Dissertation zur Erlangung des Doktorgrades
eines Doktors der Philosophie der Philosophischen Fakultät III
der Universität des Saarlandes

THE IMPACT OF CATEGORICAL AND THEMATIC RELATIONS ON ASSOCIATIVE RECOGNITION MEMORY

vorgelegt von

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Saarbrücken, 2012

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Tag der Disputation:	29 Juni 2012

ABSTRACT

Human memory enables us to store and access general world knowledge, such as concepts, facts and interrelations, on the one hand, and, on the other hand, specific information about previously experienced life events. These two types of remembered information are potentially associated with distinct but closely interacting mnemonic systems, termed semantic and episodic memory (Tulving, 1985, 1993). A body of research (Bousfield, 1953; Bower & Winzenz, 1970; Gardiner, 1988; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Greve, Rossum, & Donaldson, 2007) addressing the question of how making use of semantic information might impact episodic recognition memory for previously encountered items and relations delivered compelling support for the beneficial effect of semantic memory access on subsequent episodic recognition.

Of crucial importance is still the question which episodic recognition processes might be especially sensitive to semantic memory access. Episodic recognition memory is thought to be supported by two qualitatively different processes: a fast and relatively automatic familiarity enabling recognition of an item on the basis of the strength of the elicited mnemonic signal, and recollection, a slow threshold process leading to the retrieval of detailed information about the study episode (Mandler, 1980; Jacoby, 1991; Aggleton & Brown, 2006; Yonelinas, 2002; Eichenbaum, Yonelinas, & Ranganath, 2007). Recollection is known to be a primary process supporting associative recognition memory, i.e. recognition memory for relational information. Recent research, however, indicates that familiarity might also make a substantial contribution when to-be-learned items are integrated into a coherent structure by means of an existing semantic relation (Greve et al., 2007; Opitz & Cornell, 2006). The main goal of the present thesis was to explore how specific kinds of pre-existing semantic relations within to-be-remembered word pairs (categorical vs. thematic relations) might modulate the engagement of familiarity and recollection in associative recognition tasks as indexed by behavioral (Experiment 1 and 2) and electrophysiological (Experiment 1) measures. The findings support the conclusion that long-standing semantic relations act upon both familiarity and recollection. The pattern of modulation appears to depend on the type of the semantic relatedness with thematic relations giving more room for familiarity-based associative recognition and categorical relations relying upon both familiarity and recollection.

The second direction of the project followed the cross-cultural research suggesting potential differences in reliance on relational information between Asians and Westerners in categorization and memory tasks (Unsworth & Pexman, 2005; Gutchess et al., 2006). This research proposed that

different types of semantic relations might not guide task performance in East Asian participants, whereas they do so in Westerners. Experiments 3 and 4, that were procedurally similar to Experiments 1 and 2, investigated whether these putative differences might affect associative recognition processes in Chinese participants to the extent of altering the pattern of familiarity/recollection involvement observed in associative recognition tasks in German participants. The results showed that associative recognition is modulated by the type of relation in Chinese participants and, as with the German data, the pattern of results can be accounted for by differences in the nature of semantic structures thereby supporting the view of universal significance of categorical and thematic relations (Saalbach & Imai, 2007). Cross-cultural differences were also observed, but they seemed to primarily relate to the "default" processes underlying associative recognition. Whereas German participants flexibly engage familiarity and recollection in associative recognition, Chinese participants appear to mostly rely on recollection.

The findings of the present thesis provide new insights into the relationship between semantic relations and contribution of familiarity and recollection to associative recognition. From the cross-cultural perspective, novel evidence is obtained tentatively suggesting that the nature of semantic relations might have somewhat similar effects on associative recognition in German and Chinese participants, even though basic processes underlying performance on such tasks could be different.

ACKNOWLEDGMENTS

With all my gratitude, I would like to mention here several people who contributed in various ways to the present thesis.

First of all, I am deeply thankful to my supervisor Prof. Dr. Axel Mecklinger for his patient guidance, precious instructions and constant encouragement throughout the work.

I would like to express my gratitude to Prof. Dr. Matthew Crocker for gladly agreeing to perform as a reviewer of the thesis.

Data collection in China would not have been possible without contributions of Prof. Dr. Xuchu Weng and Dr. Jiongjiong Yang.

My warmest and very special thanks go to people from our lab who were always there to offer any kind of knowledge, technical support, useful advice or just a friendly word of encouragement, above all Dr. Bertram Opitz, Regine Bader and Dr. Emma Bridger.

I would like to thank Iris Wiegand, Irina Schweizer, Prisca Wagner, as well as my Chinese friends and colleagues Dr. Shao Hanyu, Xu Guifang and Zhao Jing for their help with data collection.

I will be always indebted and grateful to my far away and yet so close a family for their eternal love and understanding. Evgeny Kriukov remains my very special person whom I can't thank enough for both generous help at any time of the day with programming, but also for always standing by my side.

I sincerely appreciate the support of my friends that was reaching me across geographical distances.

This work was funded by a grant from German Research Foundation (IRTG 1457).

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INTRODUCTION

Long-term memory (Figure 1) is traditionally thought to be subdivided into *implicit (non-declarative)* and *explicit (declarative)* memory with the main distinction between the two systems made along the dimension of consciousness (Squire & Zola, 1996). Explicit memory system has capacity for allowing conscious retrieval of the memory content. It is thought to be further divided into *semantic* and *episodic memory* (Hodges & Graham, 2001) with the two types of memory systems providing access to different types of stored information: to concepts, fact and interrelations, i.e. shared general world knowledge and to personalized memories about previously experienced events, respectively (Hodges & Graham, 2001; Tulving, 1993; Squire & Zola, 1998; Tulving, 1985, 2002). In a broad sense, "the information in episodic memory could be said to concern the self's experiences in space and time. In contrast, the information of the semantic memory processes concerns objects and their relations in the world at large" (Tulving, 1993, p. 67). Though a current tendency (Reder, Park, & Kieffaber, 2009; Henke, 2010) is to make distinction between different memory systems on the basis of information processing characteristics rather than awareness, the differentiation between episodic and semantic memories is still widely accepted.

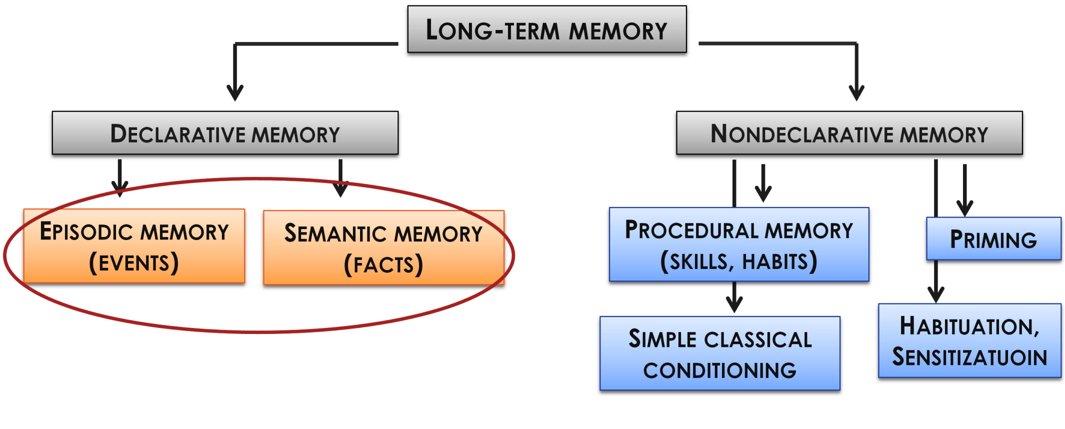


Figure 1: Adapted from Squire and Zola (1996). A model of long-term memory organization. Along the dimension of availability of conscious access to the stored information, the model makes a distinction between nondeclarative and declarative types of memory, with the latter further subdivided into episodic and semantic memory systems (circled).

The main focus of the present work is on investigating some aspects of the interaction between semantic and episodic memories. I shall first start by giving an overview of episodic recognition memory and its specific type – associative recognition memory (Chapter 1). I will consider functional processes (familiarity and recollection) involved in recognizing a prior occurrence of an item/item-combination, their underlying neural mechanisms and ways to investigate those processes by means of electrophysiological and behavioral measures. I will then turn to the semantic memory (Chapter 2) and describe current perspectives on how concepts and conceptual relations might be represented in the brain and which structures might be of crucial importance for providing access to semantic knowledge. In Chapter 3 existing evidence for the interaction between the two systems is reviewed. This chapter specifically considers how semantic relations between paired concepts affect associative recognition memory and why it is reasonable to hypothesize that the extent of the involvement of familiarity and recollection in associative recognition might be at least in part contingent upon the nature of semantic relatedness. I focus on two types of semantic relations, categorical and thematic relations, and make predictions on how they might modulate familiarity and recollection in associative recognition tasks. Chapter 4 expands the domain of research by adding to it a cross-cultural aspect. The chapter reviews evidence from reports on categorization and memory that points to putative cross-cultural differences in the significance of categorical and thematic relations. Building on these findings, I derive predictions for how the type of semantic relatedness might modulate associative recognition processes in East Asian (Chinese) participants.

CHAPTER 1

EPISODIC MEMORY

As mentioned above, information stored in the semantic memory is depersonalized and devoted of the spatiotemporal markers, such as we simply appreciate the fact that Paris is the capital of France. By contrast, a critical characteristics of episodic memory is that the stored information is associated with a prior personal experience (Tulving, 2002). One manifestation of episodic memory at work is recognizing that an item/event was previously encountered (Mandler, 1980). A typical approach to test *item recognition memory* in the laboratory setting is to offer participants to study a list of items (usually words or pictures) and then to present them with a test-list consisting of the previously studied (old) and previously unseen (new) items. For every test item, participants then have to decide whether it was studied before or not. From the earlier days of the recognition memory research various *dual-process models* were proposed (Mandler, 1980; Jacoby, 1991; Norman & O'Reilly, 2003; Diana, Yonelinas, & Ranganath, 2007; Yonelinas & Jacoby, 1995) which all converge on the assumption that performing such a recognition task might happen either by means of recollecting the details about the study episode or simply by assessing how familiar the stimulus is. These two processes, *recollection* and *familiarity*, are thought to be qualitatively distinct (Mandler, 1980; Jacoby, 1991; Aggleton & Brown, 2006; Diana, Reder, Arndt, & Park, 2006; Eichenbaum et al., 2007; Yonelinas, 2002; Rugg & Curran, 2007; Mecklinger & Jäger, 2009; Yonelinas, Aly, Wang, & Koen, 2010). Familiarity is assumed to be based on a subjective feeling of knowing that an item was previously encountered (Mandler, 1980). It is a fast-acting and relatively automatic process that can vary in the strength of the mnemonic signal but does not bring to mind specific details of a prior occurrence (Yonelinas, 2002; Rugg & Yonelinas, 2003; Mecklinger, 2006). Recollection, in contrast, provides access to detailed information about the prior encounter of an item and its associated spatiotemporal context (Yonelinas, 2002; Woodruff, Hayama, & Rugg, 2006; Rugg & Yonelinas, 2003; Rugg & Curran, 2007). Recollection is thought to be a slower and more demanding process (Rugg & Curran, 2007).

1.1 CONCEPTUALIZING FAMILIARITY AND RECOLLECTION

One of the most popular contemporary dual-process models (Yonelinas et al., 2010) is a *dual-process signal detection model (DPSD)* proposed by Yonelinas and Jacoby (1995) (see also Yonelinas (2002). The critical assumption of the model is that familiarity and recollection are in part independent processes as depicted in Figure 1.3 A with familiarity constituting a *continuous signal-detection process* and recollection – a *threshold process* (Yonelinas & Jacoby, 1995). All stimuli occurring in the experiment have a certain degree of familiarity with some being more and others - less familiar. This also concerns new items which have some degree of pre-experimental familiarity of varying strength represented as Gaussian distribution (Figure 1.1). Encountering items during the study increases pre-experimental familiarity by some constant (Yonelinas & Jacoby, 1995) thus the distribution of old items will be also Gaussian but shifted towards the upper limit on the familiarity scale (Figure 1.1), yielding overall greater familiarity for those stimuli that were recently encountered in the study phase. Familiarity-based recognition is then based on the *quantitative* assessment of the signal: a participant sets up a criterion on the familiarity strength scale and if an item's familiarity strength exceeds the criterion, she accepts it as old. Accordingly, if an item's familiarity strength is below the criterion, it gets rejected as new.

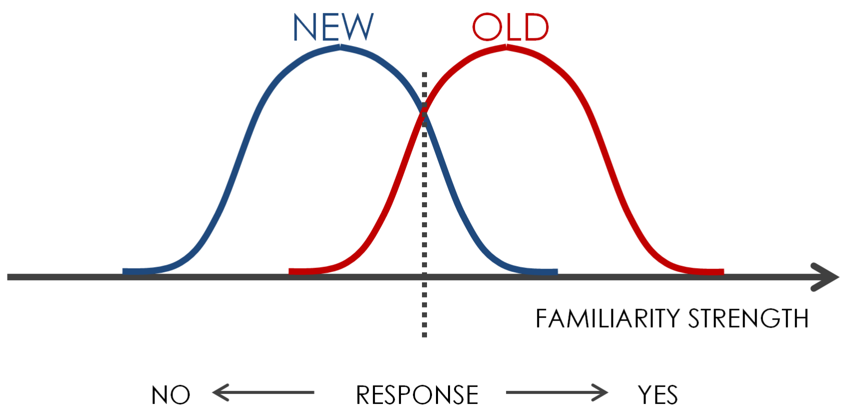


Figure 1.1: Adapted from Yonelinas and Jacoby (1995). Familiarity as a strength-based process. All items possess a certain degree of familiarity therefore familiarity signal has Gaussian distribution. Old items, due to previous encounter during the study phase, appear overall more familiar than unstudied new items. When performing a recognition task on the basis of familiarity, a participant adopts a response criterion (dotted vertical line) with items exceeding the criterion receiving a "yes-old" judgement and items falling below the criterion being rejected as unstudied ("no").

In contrast to familiarity, Yonelinas conceptualizes recollection as a threshold process: for some stimuli, recollection threshold will be exceeded yielding the recovery of specific *qualitative* information about the details of a prior episode and a "yes-old" recollection-based judgment. For other stimuli, the threshold will not be reached and the recovery of the study episode will fail (Figure 1.2). In the latter case, however, there still remains a possibility that an item can be recognized on the basis of familiarity.

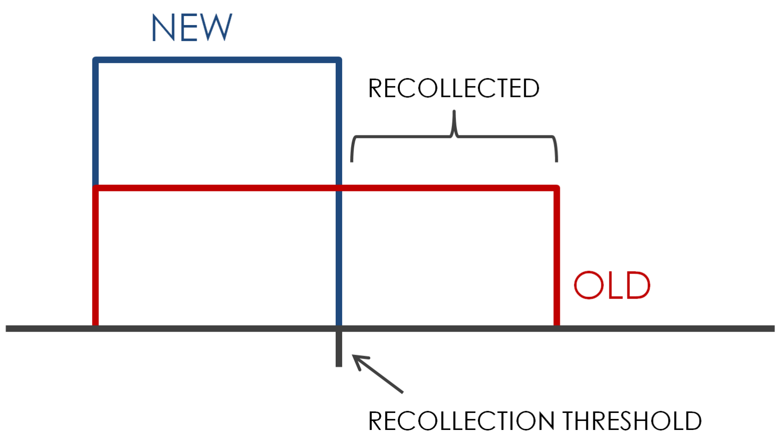


Figure 1.2: Adapted from Yonelinas et al. (2010). Recollection as a threshold process where some items, falling above the recollection threshold, will be recollected and items falling below the threshold will yield no recollection of study episode details.

Conceptualizing familiarity and recollection as qualitatively distinct processes in accordance with DPSD predicts that they should be sensitive to different types of recognition demands (for a review see Yonelinas, 2002). First, recognizing a previous occurrence of an individual item should be well supported by both familiarity and recollection. In contrast, retrieval of details about the study episode (e.g., source information, as “when” or “where” the item was seen; relational information about several items) should necessitate recollection. Next, due to distinct temporal characteristic of the two processes, familiarity-based recognition is not expected be affected by limiting the recognition decision time (e.g., setting a response-deadline in recognition experiments) while recollection-based recognition is predicted to drop. Also, as recollection is thought to be a more resource consuming process, it is predicted to be more affected when additional cognitive demands are placed on participants such as when dividing attention during the recognition test. Importantly, representing distinct functional processes, familiarity and recollection are expected to be supported by different brain structures, and to have distinct behavioral and electrophysiological signatures.

An alternative perspective on recognition is offered by *single-process models* that argue against understanding recognition memory in terms of contributions of strength-based familiarity and threshold-based recollection (Dunn, 2004; Slotnick & Dodson, 2005; Squire, Wixted, & Clark, 2007; Wixted, 2007). Instead, models of this class (Figure 1.3 B) propose that both familiarity and recollection are single strength processes (Wixted, Mickes, & Squire, 2010), therefore making distinction between the two is thought to be redundant as it is enough to assume only one continuous unidimensional strength-like process (Wixted, 2007). According to the models, recognition decisions depend on the strength of the mnemonic signal as well as on the place of the decision criterion: items for which mnemonic signal falls above this criterion are recognized as previously encountered, items with a signal strength below the threshold are endorsed as previously unseen. This is basically similar to how familiarity-based recognition decisions are made according to DPSD (Figure 1.1). Single-process models assume that stronger memories yield the retrieval of contextual/source information (mapping onto recollection in dual-process models) and weaker memories being unable to do so (mapping onto familiarity, respectively). According to the models, the same brain structures, and firstly hippocampus, are thought to be involved in the retrieval of all memory types (Wixted et al., 2010; Jeneson, Kirwan, Hopkins, Wixted, & Squire, 2010), that is both familiarity and recollection-based memories as interpreted by dual-process models.

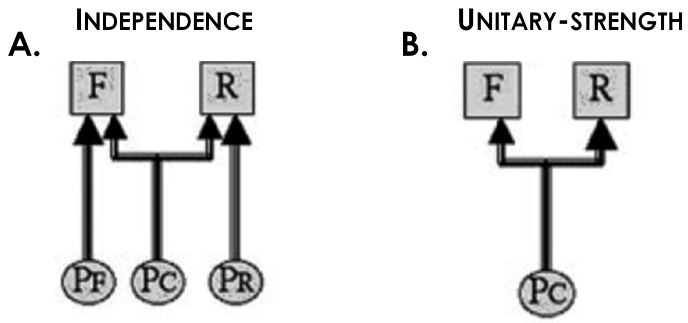


Figure 1.3: Taken from Montaldi et al. (2006). Illustration of how single-process and dual-process models understand processes involved in recognition memory. Dual-process models (panel A) assume a common (Pc) but also two independent processes (Pf and Pr) contributing to familiarity and recollection, respectively. Single process models (panel B) assume one common (Pc) single strength process and thus make no distinction between familiarity and recollection considering it as redundant.

Though there is still no universally-accepted model of recognition memory, single-process models seem to have difficulties accounting for a number of recognition memory phenomena which don't posit a problem for dual-process models (for a review of arguments, see Diana et al. (2006); Yonelinas (2002)). To list a few, retrieving distinct types of information (e.g., item vs. source/associative) was shown to have different time courses (Hintzman, Caulton, & Levitin, 1998) (with item information being retrieved faster), different electrophysiological (D. I. Donaldson & Rugg, 1998; Curran, 2000) and behavioral correlates (Yonelinas, 1997) as well as different fMRI activations (Giovanello, Schnyer, & Verfaellie, 2004). Below I review some of the neuropsychological evidence in favour of dual process models and describe two models (Eichenbaum et al., 2007; Norman & O'Reilly, 2003) of the functional separation within the medial-temporal lobe structures representing separate contributions of familiarity and recollection to episodic recognition.

1.2 DISSOCIATING FAMILIARITY AND RECOLLECTION

1.2.1 FUNCTIONAL DISSOCIATION IN THE MEDIAL-TEMPORAL LOBES

Functional dissociation between familiarity and recollection proposed by dual-process models has led to an extensive research on brain regions that might support these two distinct forms of memory. There is a wide agreement in literature (Aggleton & Brown, 2006; M. W. Brown, Warburton, & Aggleton, 2010; Eichenbaum et al., 2007; Diana et al., 2007; Henke, 2010) that *MTL (medial-temporal lobe)* is one of the most critical structures for episodic memory. Functional neuroimaging research with healthy participants, patient research and animal lesion studies provided extensive evidence for distinct roles of different MTL subregions (parahippocampal region consisting of perirhinal, enthorhinal and parahippocampal cortices; and hippocampus proper, Figure 1.4) in recognition memory (for a review, see M. W. Brown & Aggleton, 2001; Diana et al., 2007; Eichenbaum et al., 2007; Ranganath, 2010; Montaldi & Mayes, 2010).

The recurrent proposal is that perirhinal cortex (anterior medial temporal lobe) responds in a way that is predicted for familiarity-based recognition, while parahippocampus and especially hippocampus exhibit behavior compatible with that expected of recollection. For example, a number of studies (Yonelinas, Hopfinger, Buonocore, Kroll, & Baynes, 2001; Cansino, Maquet, Dolan, & Rugg, 2002) showed that correctly retrieving source information, linked to recollection-based recognition, is associated with enhanced hippocampal activity. In a study by Weis et al. (2004) participants learned pictures presented in one of the four different single color-scales. At test, they saw grey-scale pictures and for each picture had to make an old/new decision with additional source-color decision for "old"-responses. Contrasting old-source-correct responses with old-source-incorrect ones yielded higher activity in the bilateral hippocampus and parahippocampal cortex, highlighting the role of these regions in retrieving source information. In turn, operationalizing successful item memory that presumably predominantly relies on familiarity as a contrast between the activity of old-source-incorrect responses and misses (old items rejected as "new") yielded a decrease in activity in the anterior MTL. In accord with this finding, other experiments (Montaldi et al., 2006; Daselaar, Fleck, Dobbins, Madden, & Cabeza, 2006) also observed that perceived familiarity strength in an inverse manner modulates activity in the anterior parahippocampal gyrus. Findings originating from investigations of encoding (Ranganath, Cohen, Dam, & D'Esposito, 2004; Davachi, Mitchell, & Wagner, 2003) confirm this dissociation: they demonstrate that successful source recognition is associated with enhanced hippocampal and parahippocampal activations during the encoding, while successful item recognition is associated with activations in the perirhinal cortex (however see Staresina, Duncan, & Davachi, 2011).

Single-process models, however, deny this functional dissociation: they suggest that hippocampus is involved in both familiarity and recollection-based recognition (Kirwan, Wixted, & Squire, 2010). These models propose that hippocampal signal is detected in the fMRI during the retrieval of strong memories typically accompanied by recollection of the details, with weaker memories simply not having strong enough a signal to be detected when compared to the resting-state hippocampal activity (Wixted, 2007). Yet, accumulating investigations with patients with a damage to MTL structures keep on providing compelling evidence for a double dissociation in the MTL. Amnestic patients with damage limited to hippocampus show profoundly impaired performance in relational recognition (Holdstock, Mayes, Gong, Roberts, & Kapur, 2005; Konkel, Warren, Duff, Tranel, & Cohen, 2008; Giovanello, Keane, & Verfaellie, 2006) and recall (Aggleton et al., 2005; Holdstock et al., 2005; Vargha-Khadem et al., 1997) that is on tests which are predicted to require extensive involvement of recollection for the successful completion of the task. Amnestic patients' performance on item recognition tasks is, however, less impoverished (Aggleton et al., 2005; Holdstock et al., 2005; Yonelinas, Kroll, Dobbins, Lazzara, & Knight, 1998; Konkel et al., 2008) suggesting that familiarity-based recognition is in part spared in such patients. Contrary to that, Bowles et al. (2007) reported the results from several recognition memory experiments with a patient who had undergone left anterior temporal lobe resection that spared hippocampus. Converging evidence from remember-know and ROC procedures suggested that the patient was selectively impaired in relying on familiarity during the recognition tests. In one experiment Bowles et al. aimed to tap into familiarity and recollection by exploiting previous knowledge (Hintzman et al., 1998; Yonelinas, 2002) about the temporal dynamics of the two processes, specifically, earlier availability of familiarity than recollection (Experiment 4). Using a response deadline procedure, in which time to make an old/new decision during the recognition memory test was either 2000ms or limited to 400ms, they showed the patient's performance was equal to that of control participants under a longer response deadline. In contrast, her performance was severely impaired under the shorter deadline indicating a selective impairment in familiarity-based recognition.

1.2.2 MODELS OF MEDIAL TEMPORAL LOBE CONTRIBUTIONS TO EPISODIC RECOGNTION

Building on various findings from recognition memory research and the analysis of anatomical connectivity, M. W. Brown and Aggleton (2001) (see also Aggleton & Brown, 1999; M. W. Brown et al., 2010) put forward a neuroanatomical model of episodic recognition memory that proposed the existence of separate though interleaving systems: hippocampal system, critical for recollection-based recognition, and perirhinal system, essential for familiarity. Some years later, Eichenbaum et al. (2007) (see also Diana et al., 2007; Ranganath, 2010) proposed a new functional model of the MTL *(Binding of Items and Contexts model, BIC)*. Based on neuroanatomical organization of the MTL, this model highlighted different functional roles that rerirhinal cortex, hippocampus, and also parahippocampal cortex play in recognition memory (Figure 1.4). Anterior portion of the parahippocampal region (perirhinal cortex) receives inputs from unimodal association areas of the neocortex, that is information about individual items and their features. In contrast, parahippocampal cortex receives inputs from polymodal areas that process spatial (contextual) information. The two pathways converge in hippocampus that binds together item and contextual information or item-item combinations supporting the encoding of the whole study episode. At test, item recognition which does not necessarily involve the retrieval of the contextual details can,thus, be supported by familiarity reactivating item memory traces in perirhinal cortex. Importantly, the model suggests that familiarity strength should be inversely related to the activity in the perirhinal cortex: more familiar items have easier-to-access and "more efficient" representations (Diana et al., 2007) thus leading to a decrease in activation for highly familiar items. In contrast, retrieval of details of the study episode is accompanied by reactivating the study episode pattern and is necessarily accompanied by enhanced hippocampal/parahippocampal activity.

Norman and O'Reilly (2003) (O'Reilly & Norman, 2002; Norman, 2010) developed a neurocomputational model of recognition memory that attributes functional differences within MTL

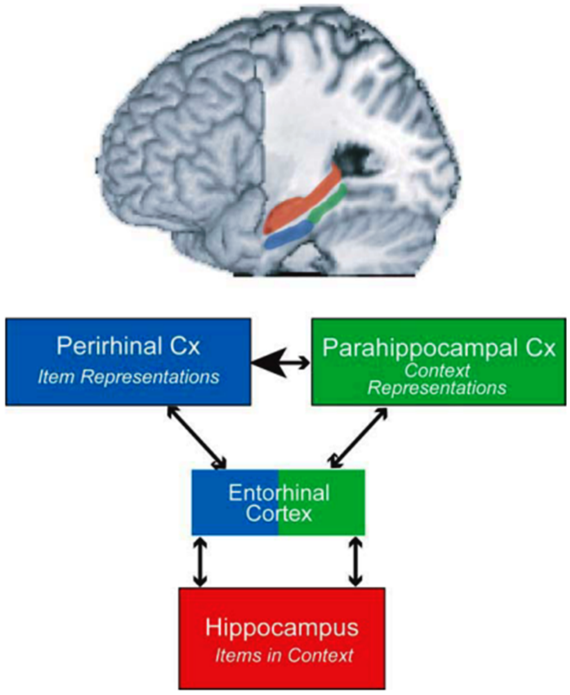


Figure 1.4: Taken from Ranganath (2010). Schematic representation of functional organization of the MTL according to the BIC model. The figure shows different MTL regions implicated in recognition memory and anatomical connections between them. Perirhinal cortex, thought to provide access to item representations, and parahippocampal cortex, enabling access to context representations, via entorhinal cortex feed information into hippocampus, which binds the two types of information together forming item + context representations.

structures to differences in neural activation patterns. The model is based on a *Complementary Learning Systems framework (CLS)* that distinguished between two basic types of knowledge acquisition-learning specifics and generalities- and suggests existence of separate neuronal systems with that operate differently to accomplish these goals. Taking into account anatomical and physiological properties of brain structures, they proposed that hippocampus is engaged in the first type of learning. Its sparse neural firing levels result in distinct patterns of activation for every bit of the incoming information ("pattern separation" process) leading to the rapid encoding of the specifics of each study episode. During recognition, presentation of a part cue is sufficient for hippocampus to complete the entire stored pattern, such as in cases when corresponding contextual information is retrieved upon a presentation of an item-cue. In contrast to hippocampus, neocortex is involved in extracting commonalities from different bits of the incoming information. Characterized by broad patterns of neural activation, it assigns overlapping representations to similar study episodes, thus encoding shared properties more efficiently than specifics. Through multiple presentations of the same incoming information, representations get less widespread and more sharpened (yielding weaker strength of the signal). During recognition, neocortex reactivates neural patterns learned during the encoding, but not being able to deliver detailed information about the episode it supports recognition through providing different levels of its activation strength. Consistent with neuroimaging results outlined above, the model predicts that more familiar items, having sharpened representations, produce weaker activation patterns at test, whereas less familiar items, having broad activation patterns, produce stronger levels of activation.

Having outlined neuropsychological evidence for the role of different MTL structures in supporting familiarity and recollection as well as neural mechanisms assumed to underlie these processes, I now turn to considering how familiarity and recollection are manifested in behavioral and neuroimaging measurements. Of a critical relevance for the present work, are behavioral correlates of familiarity and recollection provided by the *Remember-Know procedure* and electrophysiological correlates delivered by *event-related potential technique*. Below I describe these two measurement methods and review some of the evidence for why they provide reliable indices of familiarity and recollection.

1.3 MEASURING FAMILIARITY AND RECOLLECTION

1.3.1 REMEMBER-KNOW PROCEDURE

The Remember-Know (*RK*) procedure proposed by Tulving (1985) is a well-recognized method for dissociating between familiarity and recollection on the basis of subjective reports of participants about mnemonic processes they engaged in recognition (for a review see Gardiner & Richardson-Klavehn, 2000). In this procedure, prior to being offered a recognition memory test, participants are informed about the two types of recognition: recognition of the basis of feeling of knowing vs. recognition on the basis of remembering with retrieval of specific details about an item. During the recognition test, for every trial participants have to monitor mnemonic processes they rely on, and provide either a two-step or a one-step recognition response. In ttwo-step response procedure (Mandler, 1980), participants first make an old/new judgement and then, for each item identified as old indicate whether they relied on feeling of knowing (“Know”-response, K) or on remembering (“Remember”-response, R) (Tulving, 1985; Gardiner, 1988). In one-step procedure (Yonelinas & Jacoby, 1995), old/new responses and memory-state judgments are combined such that after seeing an item a participant is given a triple response option: Old-Know, Old-Remember, New.

Assessing the results of the RK procedure involves calculating the proportion of R- and K- responses, taken to reflect recollection and familiarity-based recognition (Tulving, 1985). This calculation is based on the assumption that familiarity and recollection are mutually exclusive processes: in the original test instructions, Tulving defined familiarity as recognition in the absence of recollection, accordingly designing the procedure to allow for only one memory state response for each item classified as old – either recollection or familiarity (Yonelinas & Jacoby, 1995). Yet, according to the independence assumption (Mandler, 1980; Jacoby, 1991), familiarity and recollection are independent processes, and, thus, mapping familiarity solely on the proportion of K-responses gives an estimate of familiarity in the absence of recollection without taking into account those trials on which familiarity was operating along with recollection. To avoid such an underestimation, familiarity is therefore computed as probability that an item will receive a Know response divided by the opportunity that a participant has to make a Know judgment (that is, whenever recollected failed), i.e., K = Hit K / (1 – Hit R) (Yonelinas & Jacoby, 1995; Yonelinas, 2002), by this yielding an measure of familiarity that is independent of recollection.

It is noteworthy to mention a long-lasting debate whether the RK procedure indeed measures recollection and familiarity per se (Yonelinas et al., 1998; Yonelinas, 2002; Roediger, Rajaram, & Geraci, 2007; Diana et al., 2006) or rather different degrees of memory strength or confidence (W. Donaldson, 1996; Hirshman, 1998; Dunn, 2004; Wais, Mickes, & Wixted, 2008; Rotello & Zeng, 2008; Wixted, 2009). Because remember-know judgments are based on introspective participant reports, it might be difficult to assure that participants make a distinction between two different memory states. Instead, participants might simply misunderstand the instructions and associate Remember and Know responses with weak and strong memories. By this, a participant adopts two decision criteria: *criterion C* that separates items to be endorsed as old and new, and a *remember criterion RC* that is placed higher on the memory-strength scale than criterion C. Memories exceeding the criterion RC receive a Remember-response, those falling between criteria RC and C are endorsed as Know, and those failing to reach even criterion C classified as new (W. Donaldson, 1996; Hirshman, 1998; Hicks & Marsh, 1999). Adopting a liberal bias during the test should by this affect the shift of both RC and C criteria towards the weaker end on a signal strength dimension. By contrast, adopting a conservative bias should shift both towards the higher strength end (Postma, 1999).

In accord with this, one investigation (Hicks & Marsh, 1999) that manipulated task demands at test reported that asking participants to respond Remember-Know in one instead of two-steps inflated R- and K- false alarm rates suggesting that participants shifted their response criterion towards a more liberal one in one-step procedure for both recollection and familiarity responses. The intuition is that the criterion dividing R and K responses should not shift if participants indeed responded on the basis of two distinct memory states. To further explore this issue, Eldridge, Sarfatti, and Knowlton (2002) conducted another experiment to compare the two procedures. In addition to R and K options, they also included a Guess-option (Experiment 2) as suggested by Gardiner, Ramponi, and Richardson-Klavehn (1998). This served to minimize the inclusion of pure guess-based responses into K and R categories and to underscore participants perception of the task in terms of the distinction between different memory states rather than memory strength assessment. Eldridge et al. showed that procedure manipulation (one vs. two step) primarily affects Know- and Guess-responses (specifically, false alarm rates) but not R-responses – the result consistent with the DPSD view (Yonelinas, 2002) in that given signal-strength based nature of familiarity, criterion shift should primarily affect this process and not threshold-based recognition.

Several other studies (Rajaram, 1993; Gardiner & Java, 1990) directly compared RK measures with low/high confidence judgements and showed that there is no one-to-one correspondence between these measures. For example, Rajaram (1993) primed words on which a recognition task had to be performed by a short (50ms) masked presentation of the same or a different word during the test phase. In line with her expectations that familiarity should be especially sensitive to the effects of perceptual match, she observed that targets and lures preceded by perceptually identical primes attracted more K-responses than those preceded by non-identical primes. In contrast, when participants had to make sure/unsure judgments following old/new decisions, no selective enhancement of low confidence responses was found indicating that confidence judgments may not be directly related to remember-know responses.

Neuropsychological research also provided evidence for R- and K-judgments being associated with distinct mechanisms. For example, an fMRI study by Eldridge, Knowlton, Furmanski, Bookheimer, and Engel (2000) employing an RK procedure showed that activity in hippocampus was selectively enhanced for R-responses compared to K-responses, misses and correct rejections. Another fMRI study (Montaldi et al., 2006) employed a modified version of the RK procedure, in that participants studied pictures of complex scenes and later performed a recognition test by classifying pictures as new, recollected or familiar to a certain degree (weakly, moderately or strongly familiar). While recollection-based responses activated hippocampus more than all other types of responses (see Yonelinas, Otten, Shaw, and Rugg (2005) for a similar observation), activity in the perirhinal cortex was graded according to the degrees of familiarity-based responses (decreasing activity with increasing familiarity strength). This finding suggests that subjective participant reports about familiarity and recollection-based recognition are associated with distinct neural processes.

Other studies demonstrate that R and K responses should be associated with independent processes by building on predictions about differential procedural characteristics of recollection and familiarity. Consistent with assumptions of the DPSD that recollection should support retrieval of contextual information, whereas familiarity should predominantly engage in item recognition, Perfect, Mayes, Downes, and Eijk (1996) reported that retrieval of spatiotemporal study context was more likely to be associated with items to which correct-Remember than correct-Know responses were given. Dudukovic and Knowlton (2006) offered participants to study picture-word pairs and then gave an item (word) recognition test accompanied by RK responses. Participants were brought back to the lab after a retention interval of 1 week and were again given an RK item recognition test in which for RK endorsed items they also had to report contextual information (paired associate, picture color, position on a screen). Duducovic and Knowlton observed that for R-endorsed items participants retrieved more contextual information than for K-endorsed ones. They also reported that those items that were recollected in the first test and were later recognized on the basis of knowing did not yield the retrieval of contextual memories, suggesting that conversion of recollection-based recognition to familiarity-based one is accompanied by a loss of contextual details.

Patient research likewise delivers evidence for associating remember-know judgments with independent processes. Mayes, Holdstock, Isaac, Hunkin, and Roberts (2002) showed that patient YR, suffering from a damage to hippocampus, while being profoundly impaired on recall tests, showed normal levels of K-based correct recognition. There is a robust correspondence of the results obtained with R-K procedure with those delivered by other behavioral methods, such as ROC and process-dissociation procedure (Aggleton et al., 2005; Yonelinas et al., 1998; Yonelinas & Jacoby, 1995), as well as with electrophysiological results, as reviewed in the next section. In sum, this speaks in favor of dual-process interpretation of the RK, therefore in the present work we make use of the RK procedure with an idea in mind that it allows to tap into distinct mnemonic processes.

1.3.2 ELECTROPHYSIOLOGICAL CORRELATES OF FAMILIARITY AND RECOLLECTION

Event-related potentials *(ERPs)* provide a valuable technique for investigating processes involved in episodic recognition (for reviews see Friedman & Johnson, 2000; Mecklinger & Jäger, 2009). In ERPs, electrodes are placed on the scalp to capture on-line electroencephalographic activity elicited in response to certain types of stimuli. The recorded data is then processed off-line, artifacts related to non-cognitive activity are corrected (such as, e.g., blinks and eye-movements) and periods of electrophysiological responses are averaged to reduce a signal-to-noise ratio, thus in the end yielding activity related to the task-related processing of the stimulus (Picton et al., 2000; Mecklinger & Jäger, 2009). ERPs provide information about the scalp distribution of the activity, its latency, amplitude and frequency characteristics, and most importantly very precise information about the temporal dynamics of the cognitive processes (see Luck (2005) for a comprehensive overview of the cognitive ERP technique).

In Y/N recognition tests, ERPs are recorded during the test phase and then responses elicited by correctly recognized old items are averaged and compared with those elicited by correctly rejected new ones in order to tap into the processes involved in old/new discrimination. Of crucial importance here are two ERP responses showing a consistent sensitivity to old/new discrimination - so called *early frontal* and *late parietal old/new effects*. These effects are characterized by more positive-going waveforms for correctly recognized old items than correctly rejected new items 300 – 600ms post-stimulus over frontal electrodes and 500 – 800ms over parietal electrodes, respectively (Figure 1.5). Introducing experimental manipulations at encoding and retrieval targeting into evoking familiarity and/or recollection based-recognition during the test phase allowed to link the early frontal old/new effect to familiarity and late parietal old/new effect to recollection (Curran, 2000; Rugg & Curran, 2007) (for an alternative perspective see Voss & Paller, 2009).

A classical investigation in support of this link was conducted by Rugg et al. (1998). Building on the idea that deeper processing during the encoding should promote recollecting the details of the study episode at test (Craik, 2002, see Section 2.3.2 for a detailed review of the Levels of Processing Account), encoding instructions were manipulated such that participants studied words either in the context of an alphabetic judgment task (shallow processing) or a sentence generation task (deep processing). As Figure 1.5 shows, regardless of the encoding condition ERP waveforms elicited by correct-old (hit) were more positive-going than correct new responses (correct rejections) at test phase in the 300–500/600ms time window on frontal electrodes. Critically, the early frontal old/new effect could reliably differentiate between hits and misses (incorrectly rejected studied words) in the shallow condition implying that the early frontal old/new effect cannot be simply explained by prior exposure to some items at study (implicit memory manifested in priming effects) but instead indexes a form of explicit episodic memory access, namely familiarity. In contrast, in the 500/600–800ms time window only correctly responded to items from the "deep" encoding condition yielded more positive waves than correct rejections an indication that this effect might be related to recollection of the details of the study episode.

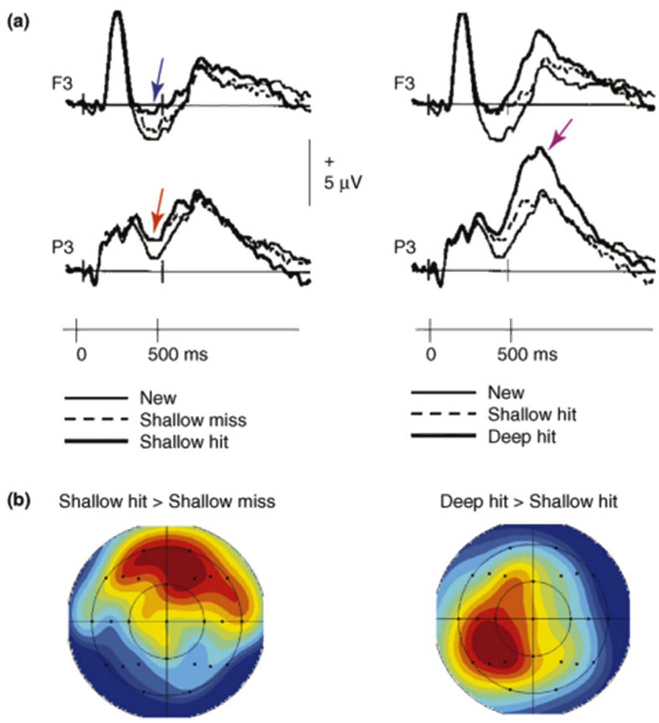


Figure 1.5: Taken from Rugg and Curran (2007). Based on the results of Rugg et al. (1998), the Figure illustrates typical early frontal and late parietal old/new effects: (a) waveforms and (b) their corresponding scalp distributions (300-500ms and 500-800ms post-stimulus).

Another seminal study, Curran (2000) dissociated ERP signatures of familiarity and recollection by introducing manipulations to the test phase. Participants studied a list of words that were either presented in singular or plural form. At test, participants were exposed to another list within which some words were presented with the intact plurality, some - with reversed plurality, and some words were completely new. Participants had to accept only those words as old that preserved their plurality from study to test and reject all other words as unstudied. Comparing the waveforms elicited by correctly recognized old words and incorrectly accepted as old reversed-plurality words revealed early frontal old/new effect (300-500ms) was not reliably different for intact and reversed plurality test words (lures), but that during the late time window (400-800ms) at the parietal sites words studied in the same plurality condition elicited more positive-going ERPs compared to the related lures. Curran interpreted these results as evidence for linking late-parietal old/new effect to the recollection of the plurality of the studied words and the early frontal old/new effect - to familiarity of studied words irrespective of plurality information.

To a similar conclusion speak the results of another study (Curran & Hancock, 2007) targeting at source recognition – a process assumed to heavily load on recollection. Participants first studied novel faces along with occupation information. At test, they had to discriminate between previously studied and unstudied faces and for each face identified as old, then to decide whether they could remember any additional details from the study episode, such as occupation. While early-frontal old/new differences were pronounced for both correctly recognized faces with and without occupational information, late-parietal old/new effect was only observed when an occupation was remembered.

Several other studies indicated that the late parietal old/new effect is linked to the retrieval of the details of the study episode (Duarte, 2004; Wilding, 1999) and is sensitive to the amount of the retrieved information about the study episode while the early frontal old/new effect discriminated between old and new items regardless of whether contextual information was retrieved or not (Vilberg, Moosavi, & Rugg, 2006). For example, Wilding (2000) hypothesized that if the late parietal old/new effect is related to recollection of the details about the study episode, then the effect should be graded with the amount of the retrieved details. In his experiment, participants heard words spoken either in a male or female voice and had to make a pleasantness or active/passive judgment. At test, participants first made an old/new judgment and then two source-judgments: in which voice was the word spoken and which encoding task was performed on it. The ERPs revealed a graded late parietal old/new effect which was largest for words with two correct source judgments compared to words with only one correct source.

Mecklinger, Brunnemann, and Kipp (2011) established a link between the two old/new effects and recognition memory processes by building on distinct temporal characteristics of familiarity and recollection. Mecklinger and colleagues demonstrated that in accord with conceptualization of familiarity as a fast-acting process (Yonelinas, 2002; Boldini, Russo, & Avons, 2004), when participants were constrained in time given to meet an old/new recognition decision, reliable old/new differences were observed only in the early time window and were greatest on frontal sites. In contrast, when no response-deadline was set, both early and late old/new effects were observed in adult participants.

In accord with a link between late parietal old/new effect and recollection, are the findings by Düzel, Vargha-Khadem, Heinze, and Mishkin (2001). They observed that an amnestic patient with a bilateral hippocampal injury exhibited a relatively normal early frontal ERP old/new effect in an item recognition test. In contrast, as compared to the controls, no late parietal old/new effect was found suggesting that while hippocampus might be involved in the generation of the late parietal old/new effect with the early frontal old/new effect is not reliant on the integrity of the hippocampus.

Combining electrophysiological measurements with RK paradigm likewise delivered compelling evidence for linking the early-frontal old/new effect with familiarity and late parietal old/new effect with recollection (Smith, 1993; Woodruff et al., 2006). In an experiment of Smith (1993) participants learned a list of words and then performed a standard RK recognition test. It was observed the magnitude of the late-parietal old/new effect associated with correct Remember judgments was greater than that associated with correct Know responses. In contrast, the early frontal old/new effect was equally large for both response-types. Another experiment (Woodruff et al., 2006) used a modified version of the RK procedure in which for every test item participants had to provide an R-response if they could remember some details about the study episode or rate their memory confidence on a 4-point scale ranging from "confident old" to "confident new". Confirming that the early frontal old/new effect is related to strength-based familiarity, the amplitude of the early frontal negativity was graded according to the strength of the mnemonic signal (confident old $<$ unconfident old $<$ confident new $<$ unconfident new) (see also Yu & Rugg, 2010). Importantly, early frontal ERPs elicited by recollected items did not differ from those elicited by high-confidence old responses. In contrasts, late parietal ERPs could effectively discriminate between the two types of responses confirming that distinction between recollection and familiarity cannot be attributed a difference in the strength of the mnemonic signal as advocated by the proponents of the single-process models (Dunn, 2004; Slotnick & Dodson, 2005; Squire et al., 2007; Wixted, 2007). Instead, the results indicate the involvement of two functionally distinct (strength-based recognition, or familiarity, vs. recollection of the specific details) and electrophysiologically dissociable processes.

Taken together, the reviewed results strongly imply that the early frontal and late parietal old/new effects reflect qualitatively and functionally distinct processes with the former showing modulations under the circumstances that should affect familiarity and the latter showing modulations as were theorized for recollection-based recognition, thus, justifying the use of ERP early frontal and late-parietal old/new effects as immediate signatures of the two processes.

1.4 CONCLUDING REMARKS

According to dual-process accounts of recognition memory, recognizing that an item was previously encountered can be accomplished by means of two distinct processes – familiarity and recollection. As reviewed in the previous sections, these processes are dissociable in terms of their functional characteristics, neural mechanisms involved, as well as in terms of their reflection in behavioral and electrophysiological measures. Experiments presented in this thesis build on the understanding of recognition memory in accordance with dual-process models and make use of RK and ERP signatures of familiarity and recollection to evaluate how these processes might be modulated by different types of semantic memory representations. The following chapter describes current perspectives on the concept of semantic memory and its relationship to episodic recognition memory.

CHAPTER 2

SEMANTIC MEMORY

2.1 STORING AND ACCESSING SEMANTIC MEMORY REPRESENTATIONS

As was mentioned before, semantic memory is a "mental thesaurus" (Tulving, 1972) which is crucial for comprehending the content of the incoming information as well as for producing new meaningful pieces of information. A nowadays widely accepted account of semantic knowledge suggests that it is stored in a distributed fashion (McClelland & Rogers, 2003; Barsalou, Simmons, Barbey, & Wilson, 2003; Tyler & Moss, 2001; Martin, 2007). For example, concepts are represented as patterns of activation throughout the cortex. When knowledge about a concept is acquired various regions coding its perceptual, motor, affective features are activated (see Figure 2.1). This multimodal pattern of activation is stored and when a concept is accessed, e.g., during language comprehension, the distributed stored pattern is then re-enacted (Barsalou et al., 2003).

2.2 ANTERIOR TEMPORAL LOBE CONTRIBUTIONS TO SEMANTIC MEMORY

While various regions might be involved in storing semantic representations, *anterior temporal lobe* (*ATL*, marked in blue in the Figure 2.2) was implicated to be of critical importance for the semantic knowledge with some scientists (Lambon, Matthew, & Patterson, 2008; K. Patterson, Nestor, & Rogers, 2007; McClelland & Rogers, 2003) thinking of it as of a "semantic hub" through which learning and accessing the distributed multimodal representations happens (for a review of alternative perspectives on the role of ATL see Simmons and Martin, 2009).

Much of the evidence for the role of the ATL in semantic memory comes from patients with semantic dementia – a variant of frontotemporal dementia, associated with an atrophy to the antero-

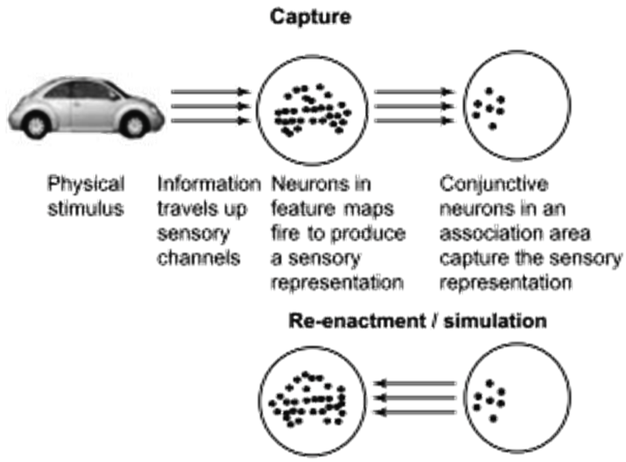


Figure 2.1: Taken from Barsalou et al. (2003). Schematic representation of how semantic representations are acquired, stored and re-activated during semantic memory access.

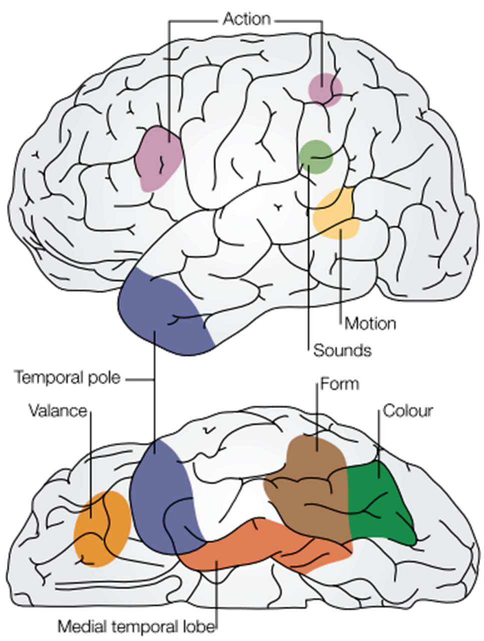


Figure 2.2: Taken from McClelland and Rogers (2003). Areas that might be involved in semantic knowledge representation by coding various features of the concept (shape, color, auditory and affective features, etc.)

lateral temporal lobe and characterized by a profound loss of semantic knowledge (Warrington, 1975; Hodges & Graham, 2001; Greenberg & Verfaellie, 2010; Snowden, Helen, Neary, & Neary, 1996). Such patients are typically impaired in tasks involving naming objects and understanding word meanings: such as category fluency and naming, word-picture matching and synonym judgment, object and word recognition tasks (Warrington, 1975; Graham, Simons, Pratt, Patterson, & Hodges, 2000; K. Patterson et al., 2007). It is noteworthy, that such impairment does not only concern the verbal domain, but also interpreting the meaning of olfactory, haptic, auditory (environmental sounds) information (Snowden et al., 1996) – findings underscoring the cross-modal role of information processing in the ATL.

2.3 SEMANTIC AND EPISODIC MEMORY

2.3.1 MODELLING RELATIONSHIP BETWEEN SEMANTIC AND EPISODIC MEMORY SYSEMS

Research with semantic dementia patients yielded some interesting observations concerning the organization of long-term memory, particularly the status of the relationship between semantic and episodic memories. It seems that in spite of semantic memory deficits, recent autobiographical memory (Hodges & Graham, 1998, 2001; Snowden et al., 1996) and episodic recognition (Warrington, 1975; Graham et al., 2000; Simons, Graham, Galton, Patterson, & Hodges, 2001) are less affected than, for instance, in amnesic patients with damage to hippocampal regions. Graham et al. (2000) conducted an experiment involving two patient groups: semantic dementia and amnestic patients with an early onset of the Alzheimer disease. Participants first studied pictures of objects in the context of a naming task tapping into semantic memory. Subsequently, participants performed a *forced-choice item recognition task* in which participants had to select a previously seen item from a set of pictures with a target stimulus being either perceptually identical or perceptually different from the studied picture. The results demonstrated a double dissociation: compared to healthy controls and amnestic patients, semantic dementia participants were severely impaired on the picture naming task, while their performance was comparable to that of healthy controls and significantly better compared to amnestic patients on the item recognition task with perceptually identical stimuli. In accord with this, using photographs of famous faces, Simons et al. (2001) could show that semantic dementia patients, though having difficulties in retrieving any semantic information when given photos of the celebrities, performed relatively well on the episodic picture recognition task which employed these photographs but not when photographs were perceptually different. Just like the study by Graham et al. (2000), these findings suggest that even though not being able to draw on the semantic knowledge participants could show episodic learning by just relying only on the perceptual information about the stimuli. The opposite pattern was observed for amnestic patients. Vargha-Khadem et al. (1997) reported that patients with early childhood amnesia resulting from the impairment of the bilateral hippocampus had partially spared semantic knowledge but were not able to remember episodic information, such as discrete life events. Further evidence likewise indicates that some very laborious semantic learning is possible in amnesia (Bayley, Wixted, Hopkins, & Squire, 2008), though its acquisition is still impaired compared to healthy controls (Squire & Zola, 1998; Manns, Hopkins, & Squire, 2003),

Findings such as these have challenged the early view of episodic-semantic memory relationship proposed by Tulving (1985)(Tulving, 1993; Tulving & Markowitsch, 1998) that episodic memory constitutes a subsystem of the semantic memory in that it is dependent on semantic memory but not vice versa. According to this view, encoding of information into episodic memory is thought to be only possible after the initial processing by the semantic memory system. It also does not appear that the integrity of the episodic memory is a necessary prerequisite for the acquisition of semantic memories as might be hypothesized if one adopts the view that semantic memories are memories abstracted from multiple encounters in various episodes, i.e. episodic memory serving as a gateway to semantic memory (Baddeley, 1988). Rather, it seems that a) acquiring episodic knowledge is not entirely contingent upon semantic memory (Graham et al., 2000; Simons et al., 2001) and b) semantic knowledge can be acquired even if episodic memory is impaired (Vargha-Khadem et al., 1997; Bayley et al., 2008). As shown in Figure 2.3, this suggests that semantic and episodic memory systems might constitute partially independent but closely interleaving memory systems, in that information from one system can feed into another, but it is not the only and necessary prerequisite for the functioning of the system (for a recent review see Greenberg & Verfaellie, 2010; Graham et al., 2000).

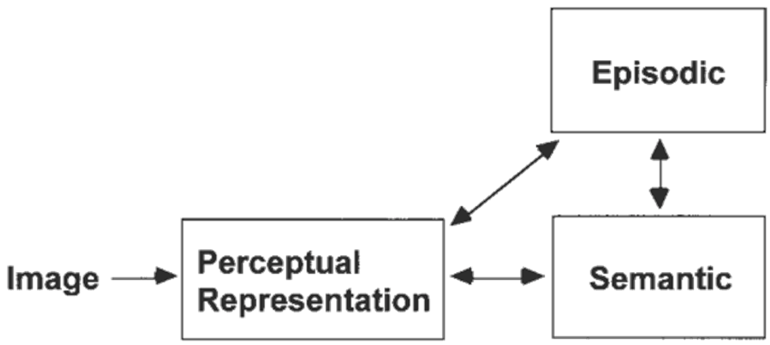


Figure 2.3: Taken from Graham et al. (2000). The figure illustrates the view according to which semantic and episodic memory systems constitute separate but closely interacting memory systems (Graham et al., 2000).

A view advanced by Reder et al. (2009) (*Source of Activation Confusion model (SAC)* suggests that episodic and semantic memories operate on the same types of representations with the difference being that episodic memory tasks requiring recollection need access to contextual information stored as so-called episode nodes, which are typically under-activated in semantic memory tasks (as well as in episodic memory tasks relying on familiarity).

2.3.2 BENEFITS OF SEMANTIC PROCESSING FOR EPISODIC ITEM RECOGNTION MEMORY

Though the precise relationship between episodic and semantic memories is still a matter of extensive research, there is no doubt about close interaction between the two systems (Greenberg & Verfaellie, 2010). Widely appreciated is that accessing information from one system seems to be beneficial for further processing by another system. For example, accessing episodic information is beneficial for semantic dementia patients: Snowden, Griffiths, and Neary (1994) showed that such patients perform better on tasks involving access to meaningful information, such as names of geographical locations, if they had some prior personal experience or connection with them. Complementary to that, Kan, Alexander, and Verfaellie (2009) demonstrated that amnestic patients with relatively intact semantic memory benefited in episodic recognition memory task from the congruence of to-be-learned information to already existing semantic representations. In their experiment, participants studied prices of different types of grocery items that were either congruent or incongruent with participants' prior knowledge of price information. They then performed a forced-choice recognition test on studied prices. Both controls and a subset of amnestic patients with a spared semantic store performed better in recognizing prices congruent with their prior semantic knowledge than incongruent.

Along with patient research, investigations with healthy individuals have managed to deliver much evidence for the close interaction between episodic and semantic memory systems. Reexamining the existing data, Craik and Lockhart (1972) (see also Craik, 2002) observed that the success of remembering information is contingent upon the kind of operation performed at encoding (*Levels of Processing (LoP) account*). They proposed that encoding a stimulus by solely capturing its perceptual features is more superficial and therefore yields potentially weaker memory traces than when encoding involves meaningful (semantic) processing which results in activating more elaborate representations and forming stronger memory traces. In accordance with this proposal, across a number of experiments (Rajaram, 1993; Gardiner, 1988; Nyhus & Curran, 2009; Ullsperger, Mecklinger, & Müller, 2000; Rugg et al., 1998) the depth of semantic processing at study was manipulated by instructing participants to encode items in a deep vs. shallow manner, by employing tasks that either endorse conceptual access (e.g., making animacy or pleasantness judgments) or minimize it (e.g., alphabetic order or legibility judgment). The convergent pattern of results suggests that more meaningful processing of information improves subsequent item recognition memory by affecting recollection- (Rugg et al., 1998, see Chapter 1 for the details on the study) as well as familiarity-based recognition (Nyhus & Curran, 2009).

A close interaction between the two systems was reported in an ERP study by Meyer, Mecklinger, and Friederici (2007). In this experiment, participants read correct sentences or those in which the final word violated the sentence either syntactically or semantically. Participants were then given a surprise item-recognition test which included studied final words from these three types of the sentences as well as completely new words. ERP results showed that words previously studied in the semantically incorrect sentences elicited a larger early frontal old/new effect than those studied in the context of the two other sentence types. Presumably, detection of the semantic violation during the study triggered intensive attempts to find ways to integrate the violating concept into the sentence frame by this additionally activating semantic representation of that concept. This in turn allowed for a more fluent and automatic familiarity-based recognition of such words during the test.

2.4 CONCLUDING REMARKS

Empirical evidence as well as theoretical models reviewed in this chapter illustrate that though possibly being partially distinct memory systems, semantic and episodic memory closely interact. Operations performed by one system seem to profit from accessing complementary types of information provided by the other system. The principal issue addressed in this dissertation project is to further explore the relationship between semantic memory representations and a specific type of episodic recognition memory – associative recognition. In the next chapter, I review the literature concerned with associative recognition memory and effect of semantic memory access on associative recognition. I then focus on two types of semantic relations – categorical and thematic – and discuss how differences in the nature of semantic representations undelying these relations might modulate associative recognition of categorically and thematically related concepts. Accordingly, research hypotheses for Experiments 1 and 2 are derived.

CHAPTER 3

FINDING RELATIONSHIP BETWEEN SEMANTIC RELATIONS AND ASSOCIATIVE RECOGNITION MEMORY

3.1 ASSOCIATIVE RECOGNITION MEMORY

The emphasis of the present work is on episodic *associative recognition memory* that is recognition of associations or relational links between several informational elements of an event (Hockley & Consoli, 1999; Giovanello et al., 2006). It is a conceptually distinct from item memory as it involves retrieving not only single items but also the relation between these items. A common way to probe associative recognition is to ask participants to study a list of paired associates and at test present them with another list in which they have to discriminate between the pairs previously seen in the same combination (old), studied in different combinations (rearranged), and completely new pairs. Inclusion of rearranged pairs in the test list ensures that participants identify old pairings on the basis of memory of a relational link and not by simply by recognizing individual items as old, i.e. on the basis of item-memory.

Involving retrieval of relational information, associative recognition memory is therefore similar to memory for item-context/item-source bindings with a difference that associative information is about a link between separate items. Similarly to item-context and source recognition memory, according to dual-process models associative memory is assumed to rely on recollection. Conceptualized as supporting primarily item-recognition in DPSD model of Yonelinas (2002), familiarity is predicted to be only relevant on recognition tests involving old vs. novel item combinations but not old vs. rearranged. Because all items in old and rearranged pairs were previously seen and thus are all roughly equally familiar, simply assessing memory strength of single items in an item pair does not allow to discriminate between old and rearranged pairs (Yonelinas, 2002; Yonelinas et al., 2010). Retrieving information about how items were paired during the encoding is then a matter of recollective experience: this aspect of the study episode either being recollected or not

(Kelley & Wixted, 2001; Yonelinas et al., 2010).

Linking familiarity with anterior parahippocampal cortex and recollection – with hippocampal/ parahipocampal regions as suggested by patient and neuroimaging data reviewed in Chapter 1, makes the link between associative recognition memory and recollection consistent with predictions of BIC (Eichenbaum et al., 2007; Diana et al., 2007; Ranganath, 2010) and CLS models (Norman & O'Reilly, 2003; O'Reilly & Norman, 2002; Norman, 2010, please refer to Section 1.2.2 for the details on both models). BIC suggests that hippocampus is involved in binding and retrieving item-context or item-item information due to the specifics of its neuroanatomical connectivity in that it receives and combines together information from "what" and "where" processing streams (Eichenbaum et al., 2007; Diana et al., 2007). According to CLS model (Norman & O'Reilly, 2003), hippocampus is involved in memorizing arbitrary item combinations due to its ability to assign separate representations to all bits of the incoming information, rapidly learn them and reinstantiate the complete learning patterns upon the presentation of part cues. In what follows I shall provide some evidence supporting the idea of associative recognition memory is driven by recollection but also outline circumstances under which familiarity might contribute as well.

3.2 CONTRIBUTIONS OF RECOLLECTION AND FAMILIARITY TO ASSOCIATIVE RECOGNITION MEMORY: INSIGHTS FROM ELECTROPHYSIOLOGICAL, BEHAVIORAL (RK) AMD FMRI MEASURES

Extensive empirical evidence obtained with ROC (Yonelinas, 1997; Jäger & Mecklinger, 2009), RK (Hockley & Consoli, 1999; Gruppuso, Lindsay, & Masson, 2007), ERP (D. I. Donaldson & Rugg, 1999; Bader, Mecklinger, Hoppstädter, & Meyer, 2010; Jäger, Mecklinger, & Kipp, 2006), fMRI (Giovanello et al., 2004; Kirwan & Stark, 2004) and amnestic patient research (Mayes et al., 2004; Holdstock et al., 2005) supports the idea that associative recognition involves a substantial amount of contribution from recollection (for a review see Mecklinger & Jäger, 2009; Mayes, Montaldi, & Migo, 2007).

For example, Giovanello et al. (2004) explicitly compared item and associative recognition in an fMRI experiment. Participants first studied word pairs in sentence generation task and then performed separate item (decide if both words appeared at study ignoring relational information) and associative recognition tests (decide if words appeared together at study). Comparing activations during the associative recognition test blocks with those elicited during item recognition test blocks revealed greater activity in the bilateral anterior hippocampus. A similar result was obtained when directly contrasting correctly responded to intact and rearranged pairs, suggesting a direct role of hippocampus in associative memory.

Comparing item and associative recognition memory in behavioral experiments using RK paradigm Hockley and Consoli (1999) observed that associative recognition was associated with more R-responses and less K-responses than item recognition. Likewise, an ERP study by D. I. Donaldson and Rugg (1998) in which participants first studied unrelated word pairs and at test had to discriminate between old, rearranged and new pairs revealed only a late parietal old/new effect, but no early frontal old/new effect implicating that recognition of associations is supported primarily by recollection, not familiarity (Figure 3.1).

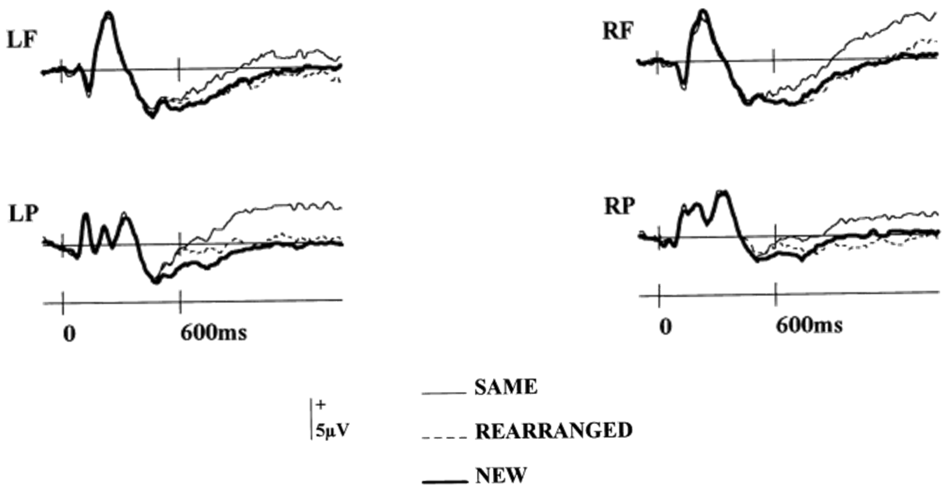


Figure 3.1: Taken from D. I. Donaldson and Rugg (1998). The results of the associative recognition memory test employing unrelated word pairs (D. I. Donaldson & Rugg, 1998). The pattern shows no reliable early frontal, but a pronounced late parietal old/new effect implicating the role of recollection in associative recognition memory. Note, that positive voltages are plotted upwards.

Nonetheless, a number of recent studies on associative recognition proved that though mostly involved in the retrieval of item information, under some circumstances familiarity can also support associative recognition such as when the several items (or item and its feature/source) are bound together to an extent that they are perceived as a single whole, as a unit and not as arbitrary pairings (Yonelinas, Kroll, Dobbins, & Soltani, 1999; Yonelinas, 2002; Quamme, Yonelinas, & Norman, 2007; Mayes et al., 2007). The idea behind the so-called *unitization hypothesis* is that with repeated experience connections between separate elements (e.g., two stems of a compound word; features of a face) are strengthened to such an extent that elements are integrated into one *unitized representation* (Graf & Schacter, 1989; Quamme et al., 2007; Mecklinger & Jäger, 2009) which basically resembles a single item representation. Such representations are thought to have inflexible, fixed configurations therefore their acquisition and retrieval can bypass hippocampal processing and be performed by neocortical regions, such as perirhinal cortex (Henke, 2010). This was indeed demonstrated by Haskins, Yonelinas, Quamme, and Ranganath (2008) who showed that unitized processing at encoding (such as combining two words into a single compound) enhanced activity in the perirhinal cortex and this activity was predictive of subsequent familiarity-based associative recognition. Complementary to that, Diana, Yonelinas, and Ranganath (2010) recently reported that integrated item-feature processing at encoding is associated with perirhinal activity during the associative recognition.

Using ERPs to tap into familiarity and recollection, Rhodes and Donaldson (2007b) measured contribution of these processes to associative recognition of three word-pair types: lexical compounds (e.g., *mars – bar*), semantically and associatively related pairs (e.g., *lemon – orange*) and semantically related but unassociated pairs (e.g., *violin – guitar*). At test all three types of relations elicited an equally large late parietal old-new effect. Conversely, the early frontal old/new effect, was present only for compounds that is in the condition in which two elements formed pre-experimentally unitized representations. A number of other studies (Diana, Yonelinas, & Ranganath, 2008; Quamme et al., 2007; Bader et al., 2010; Jäger et al., 2006; Yonelinas et al., 1999; Diana et al., 2010) also delivered a considerable support for the unitization hypothesis by showing that pre-experimentally unrelated items, when bound together during the encoding and learned as a unitized whole, can be recognized on the basis of familiarity. Quamme et al. (2007) offered participants to encode unrelated word pairs by embedding them as separate members into a sentence frame or by forming a compound from the novel pair. A group of participants was then given an associative recognition memory test during which they were instructed to respond on the basis of their feeling of familiarity for the word pair. Another group of participants performed a standard associative recognition test (Experiment 2). Quamme et al. observed that under familiarity-only instructions participants performed significantly better on word pairs encoded in the compound condition than in the sentence condition, whilst no such differences were obtained under standard recognition instructions. In another experiment (Experiment 1) Quamme et al. demonstrated that amnestic patients in spite of their general impraiment on associative recognition tests perform relatively well when stimuli are unitized into novel compounds during the encoding (see also Giovanello et al. (2006) for a similar effect of pre-experimentally existing compounds).

In some cases in the unitized condition a trade-off is observed: boost in familiarity-based recognition is accompanied by an attenuation of recollection (Ford, Verfaellie, & Giovanello, 2010; Jäger et al., 2006; Bader et al., 2010). Recent fMRI study (Ford et al., 2010) showed that retrieval of unitized stimuli (compounds) compared to unrelated word pairs was associated with activity in the left perirhinal cortex, whereas recognition of unrelated pairs showed more activation in left hippocampus than recognition of unitized pairs. In another report, Jäger et al. (2006) employed face pairs as stimulus materials. In one condition, a pair consisted of faces of two different persons and in another condition, a face was paired with its morph, thus depicting the same person and by this supporting easier unitization of the two faces into one concept. At test, participants were presented with a face for which they were asked to make an old/new response. For faces correctly identified as old, participants then saw two faces and had to decide which of them was paired with the main face during the study. Analyzing ERPs to the first face, for which correct new and correct old + correct associative judgement were given, revealed that the early frontal old/new effect was larger for words studied in the unitized condition (intra-item) than in the non-unitized one (inter-item condition, Figure 3.2). The reverse pattern was observed for the late parietal old/new effect.

In another investigation, using a procedure like that of Quamme et al. (Bader et al., 2010) compared the ERP old/new effects in recognition of word pairs that were either studied as separate members of a sentence or were unitized into a novel compound concept by means of a definition. Correct responses to pairs encoded in the sentence condition elicited a reliable late parietal

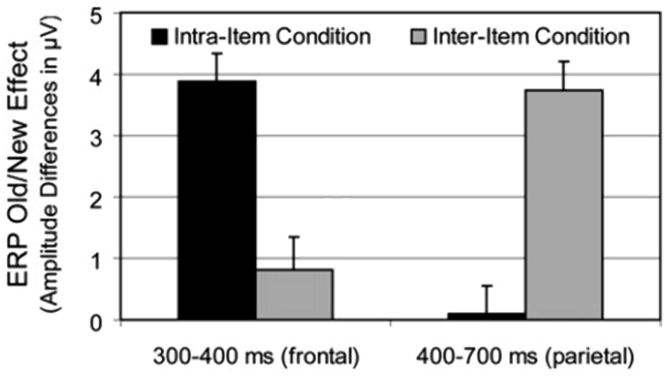


Figure 3.2: Taken from Jäger et al. (2006). The results of a study by Jäger and colleagues showing a double dissociation in the contributions of familiarity and recollection to associative recognition of unitized (intra-item) and non-unitized (inter-item) stimulus pairs.

effect but no old/new effect in the early time window (Figure 3.3). Conversely, pairs encoded in the definition condition elicited an early broadly distributed old/new effect but no reliable differences between old and new ERPs in the late time window when putative correlate of recollection is typically observed. The critical aspect of the data for current purposes is the observation that participants could make correct associative recognition responses in the absence of any electrophysiological correlate of recollection, because they could respond to these items on the basis of early familiarity-like processes.

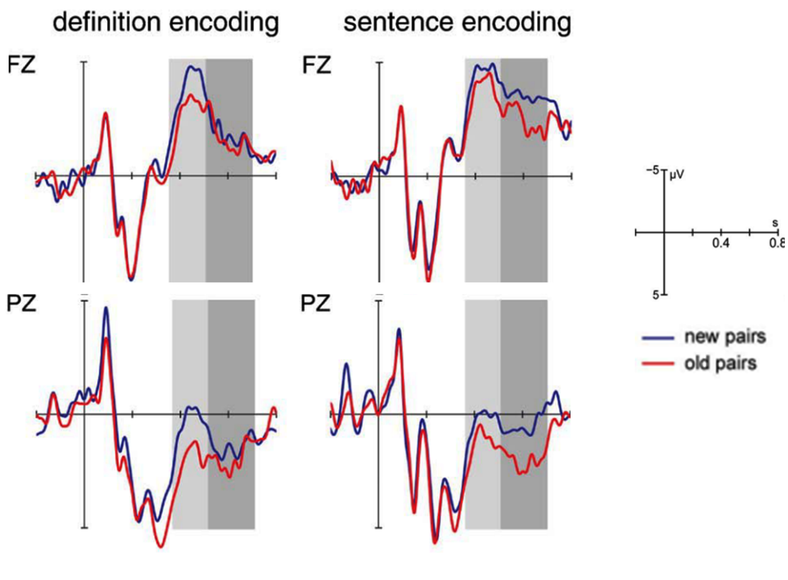


Figure 3.3: Taken from Bader et al. (2010). ERP old/new effects reported by Bader et al. (2010) showing contribution of early familiarity-like processes to associative recognition of word pairs unitized during the encoding (definition condition) and engagement of recollection in recognition of non-unitized pairs (sentence condition).

Summing up, it appears that whilst performing associative recognition tasks primarily relies on recollection, it can be supported by familiarity when paired associates are unitized and processed in a holistic manner. Of special relevance to the current work are the findings that unitized associates along with enabling familiarity-based associative recognition, might attenuate contribution of recollection in tasks of this kind.

3.3 BENEFICIAL EFFECT OF SEMANTIC PROCESSING FOR EPISODIC RECOGNITION MEMORY

As discussed in the previous chapter, episodic recognition processes are strongly affected by the level of processing during the encoding with deep semantic processing boosting single item recognition at test (details on the LoP account by Craik and Lockhart (1972) can be found in Section 2.3.2). A similar observation was made by Bower and Winzenz (1970) regarding associative memory. In their experiment, participants were instructed to learn unrelated word pairs using one of the four strategies: by repeating aword-pair during the study phase, by reading it in the sentence, by generating a sentence with a given word pair, or by forming mental images of the two words. Subsequently participants' associative recognition memory was tested with results yielding a graded pattern of recognition accuracy as a function of encoding task: performance was poorest in the repetition condition, followed by a better recognition memory in the sentence reading, then in the sentence generation and finally best in the imagery condition. Interpreting the advantage of both sentence conditions in comparison to the rote repetition condition, Bower and Winzens suggested that establishing some relation between the two items at the stage of encoding supports associative learning and improves subsequent recognition.

This interpretation is interesting in light of the fact that human semantic memory already contains knowledge about relationships between concepts, for instance, categorical relationships as in a word pair *pig – sheep* or thematic as in *sheep – farm*. A series of experiments were conducted to explore whether making use of such existing relational information might be beneficial for episodic memory. Indeed, it was shown (Bousfield, 1953; Gershberg & Shimamura, 1995) that accessing semantic relations during encoding and retrieval, such as grouping items according to a particular conceptual category or a theme (Khan, 1988), leads to recalling more items in a free recall task compared to cases when items are memorized as a randomized list. Beneficial effect of accessing existing semantic relations was also observed for associative recognition memory and associative recall (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005; M. M. Patterson, Light, Van Ocker, & Olfman, 2009; Badham, Estes, & Maylor, in press). For instance, Naveh-Benjamin et al. (2003) reported that merely learning word-pairs pre-experimentally connected by a plausible meaningful relation, i.e. a categorical relation as in *jacket – skirt*, increases associative recognition memory compared to learning arbitrarily paired words. The magnitude of this improvement is especially striking for older adults who in spite of common deficits in associative recognition tests compared to item memory tests and show an improvement in associative recognition up to the level of performance on item recognition tests when word-pairs are pre-experimentally related.

These results, however, leave open the question as to which episodic recognition processes especially benefit from the presence of a pre-existing semantic relation. Whilst associative recognition of arbitrary word associations seems to rely on recollection only (D. I. Donaldson & Rugg, 1998), using ERP indices of familiarity and recollection several recent reports suggested pre-experimentally existing relations between the paired words might support familiarity-based associative recognition (Greve et al., 2007; Opitz & Cornell, 2006; Rhodes & Donaldson, 2008).

In one such investigation (Greve et al., 2007), participants first studied paired associates that either shared a categorical membership (e.g., *rabbit – mouse*) or were unrelated (e.g., *hair – radio*), and subsequently were given a recognition test during which intact and recombined/new word pairs, cued by category labels, had to be discriminated. As is typical of associative recognition experiments, the results revealed a robust late parietal old/new effect in both conditions implicating a comparable contribution of recollection to associative recognition of categorical and unrelated pairs (Figure 3.4). In contrast, the early frontal old/new effect was larger for categorically-related than for unrelated word pairs leading Greve and colleagues to conclude that the presence of a coherent semantic structure acts upon associative recognition processes by modulating the extent to which familiarity is engaged.

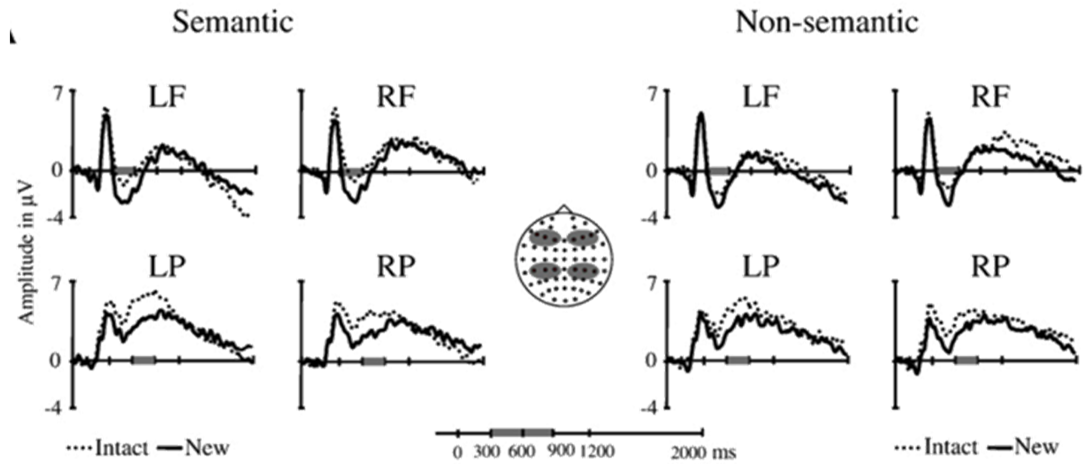


Figure 3.4: Taken from Greve et al. (2007). Illustration of the ERP old/new waveforms suggesting that semantic (categorical) relatedness between the paired items boosts the early-frontal old/new effect, whereas the late parietal old/new effect is not modulated. Positive voltages are plotted upwards.

Indirect evidence speaking to the same conclusion comes from a study by Opitz and Cornell (2006) who employed a different type of pre-existing semantic relations - long-standing thematic relations (referred to as "associative" by Opitz and Cornell). In their experiment, participants learned quadruplets of words where three words were pre-experimentally associatively related via a frequent contextual co-occurrence, e.g., *desert, camel, oasis* and the fourth word was an unrelated filler. Participants studied the quadruplets while making contextual fit judgments, which encouraged them to think about a common theme, or while making size judgments, which promoted non-semantic processing. Subsequently, participants were given a single item recognition test. The results revealed that while the recollection-related late parietal old/new effect was present for both encoding conditions, only words studied in the context of the thematic fit task elicited an early frontal old/new effect. Even though associative memory was not explicitly probed in the test phase, the results tentatively support the view that activating a common thematic frame, and by this organizing the items into a joint representation at encoding, might enhance familiarity-based recognition in the subsequent test phase.

The goal of the present work is to explicitly examine the way semantic processing might impact associative recognition by considering how different kinds of semantic relations interact with episodic processes in tasks of this kind. This was achieved here, by focusing on the differences between categorical relations (such as those employed by Greve and colleagues) and thematic relations (similar to those employed in a study by Opitz and Cornell) which have been shown to represent a distinct mechanism for organizing conceptual knowledge. In what follows, I shall have a closer look at the nature of the two types of semantic relations and then, building on previous knowledge about processes modulating associative recognition memory, outline the hypotheses for how these relations might affect associative recognition in the present experiments.

3.4 SEMANTIC RELATIONS

3.4.1 CATEGORICAL RELATIONS

Conceptual knowledge in semantic memory is not stored in a random and chaotic fashion but seems to be structured around various types of relations forming a conceptual network (Collins & Quillian, 1969; McClelland & Rogers, 2003; Caramazza & Mahon, 2003). *Categorical (taxonomic) relatedness* is one of the major ways of organizing conceptual structure (Barsalou, 1983). It follows the principle of family-resemblance (Rosch, 1975) according to which items that are conceptually or perceptually similar are usually organized under the same parent-category, e.g., *apple* and *orange* belong to the category fruits, whilst distinct items usually fall into different categories (Estes, Golonka, & Jones, 2011; Hampton, 2000; Lin & Murphy, 2001; Markman & Wisniewski, 1997). Categorical knowledge is organized among the two dimensions – horizontal and vertical (Lucariello, Kyratzis, & Nelson, 1992; Markman & Wisniewski, 1997). Horizontal categorical relations exist between the concepts of the same ontological level (categorical coordinates: e.g., *car – motorcycle*), and vertical categorical relations exist between the different levels of the taxonomic hierarchy with superordinate categories being more broad (e.g., *vehicle*), basic categories representing common categories “at the middle level of abstraction” (Markman & Wisniewski, 1997, p.54) (e.g., *car*) and subordinate categories being more narrow and specific (e.g., *limousine*). Categorical organization is an important principle of structuring the world knowledge that supports well inferential generalizations (Estes et al., 2011; Ross & Murphy, 1999), such as when inferences about the properties of concrete members of the category can be made on the basis of typical attributes of the category or prototypical members (Rosch, 1975), e.g., knowing that a *samlor* is a kind of *bike* suggests that is has wheels, it needs a driver, etc.

In the present work I predominantly concentrate on *categorical coordinates*. An essential characteristics of categorical coordinates is their resemblance to each other which typically means that the two concepts are characterized as having a high semantic feature overlap or at least as sharing many dimensions on which they can be compared (Wisniewski & Bassok, 1999). Consider categorically related concepts *cat – dog* which share a variety of characteristics, such as they both are pets that have fur, eat meat, etc, and have relatively few distinct features, e.g., can meow/bark (Figure 3.5. Perraudin and Mounoud (2009) reported the results of a rating study in which they asked participants to rate perceptual similarity of the members of categorically (*dress – pullover*) and non-categorical instrumentally related word pairs (*axe – wood*). The results revealed significantly greater perceptual similarity ratings in the categorical condition. Anticipating the next section which introduces the concept of thematic relatedness, it is worth mentioning a study (Experiment 1) by Wisniewski and Bassok (1999) which directly compared the similarity ratings given to four types of word pairs: categorically and thematically related, categorically related only, thematically related only and unrelated. In accord with Perraudin and Mounoud (2009) conditions that entailed categorical relatedness yielded significantly higher similarity ratings than thematic and unrelated ones (for a similar finding see also Estes & Jones, 2009). Neuroimaging research likewise suggests that processing categorical associates generally relies on perceptual similarities as it actively involves bilateral visual cortical areas (Kalenine et al., 2009) and precuneus (Kotz, Cappa, Cramon, & Friederici, 2002; Sachs, Weis, Krings, Huber, & Kircher, 2008). In contrast, processing of thematic items recruits a temporo-parietal network, specialized in spatial and motor processing (Kalenine et al., 2009), suggesting a different nature of semantic representations underlying such relations.

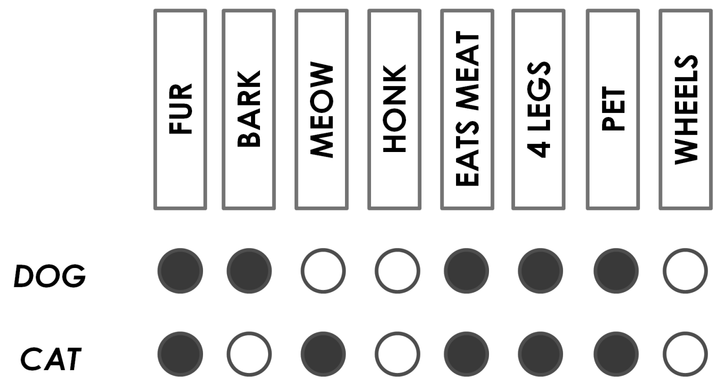


Figure 3.5: Adapted from Deacon et al. (2004). Illustration of shared and distinct features for categorically related concepts “cat” and “dog”. Individual semantic features are represented as circles. If a concepts possesses the relevant feature, the corresponding circle is filled.

3.4.2 THEMATIC RELATIONS

Thematic relations provide an alternative way of organizing conceptual network by structuring it around our knowledge of the events and common situations in the world (Hare, Jones, Thomson, Kelly, & McRae, 2009; Estes et al., 2011; Lin & Murphy, 2001; Murphy, 2001). Such relations emerge between entities participating in the same event or scene (Estes et al., 2011; Lin & Murphy, 2001) and entail a variety of interrelations among the concepts, such as functional (e.g., *knife – bread*), temporal (e.g., *morning – coffee*), spatial (e.g., *ceiling – lamp*), containment (e.g., *milk – jar*) or causal (e.g., *joke – laughter*). Importantly, unlike categorical relations, thematic relations are not based on similarity of internal properties of the related items (specific item features such as "has wheels"; "is a mammal", etc) but rather on complementary roles that the items play in a common external scenario/theme (Gentner & Brem, 1999; Estes et al., 2011; Lin & Murphy, 2001; Sachs et al., 2011; Wisniewski & Bassok, 1999). For instance, *bread* and *knife* are featurally dissimilar and belong to different taxonomic categories, yet, they play complementary roles in the common "meal" theme with *bread* fitting the thematic role slot required by the knife. Estes et al. (in press) note that a unique aspect of thematic relatedness is that it is not driven by internal properties of items per se but rather by an external situational context which integrates these items into a theme.

To avoid confusion in the terminology, it is necessary to clarify that there is no one-to-one mapping between associative relatedness and thematic relatedness, though the terms are sometimes used interchangeably (e.g., Sachs et al., 2011). In a traditional sense, concepts are considered associated if one concept brings to mind another concept which is operationally defined as probability that the item will be produced in response to a certain cue (Hutchison, 2003), e.g. cue – response pair *day – night*. Association is a separate dimension on which conceptual knowledge can be characterized (Maki & Buchanan, 2008), and both categorically and thematically related concepts can be associated as shown in Figure 3.6, e.g., *cat – dog* and *cat – mat*, or unassociated, *cat – horse* and *hammer – rock* (Hutchison, 2003; Estes et al., 2011).

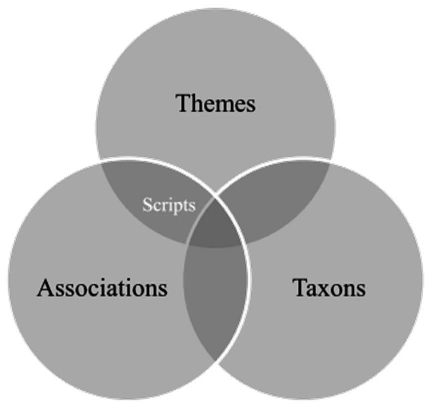


Figure 3.6: Estes et al. (2011). A schematic representation of three dimensions along which conceptual relations can be organized.

High associative strength is, however, an essential characteristics of a subtype of thematic relations - *conventional thematic relations* (alternatively termed *script*-relations, see Figure 3.6). These are salient relations with well-established representations in semantic memory (Lin & Murphy, 2001; Estes et al., 2011), such as in *pen - note*. Conventionalization of the relations happens as interacting items frequently reappear in the same real-world situation (Estes et al., 2011), such as *pen* and *note* typically co-occurring in office-scenes. Through multiple exposures to the same contextual item combination, items get tightly associated and, by this, unified into coherent and easy-to-access representations (Opitz & Cornell, 2006) with the prototypical context serving as "the 'glue' that binds objects in coherent scenes" (Bar, 2004, p. 617). Such relations are easily identifiable even when presented outside of an appropriate context. In contrast to that, some thematic relations simply arise from the affordances of the current situation, e.g. *rock – nail* (Estes et al., 2011). Identifying the relationship between the two items requires supporting contextual information: e.g., in a situation where a hammer is unavailable one can use a rock to hammer in the nails. Thus, the critical distinction between the two types of thematic relations is that conventional relations reflect the standard role that two items play in a prototypical situation and by this are highly associated with each other via an integrating contextual frame. The focus of the present work is on *conventional thematic relations* to which I will refer from now on simply as thematic relations.

3.4.3 IMPORTANCE OF CATEGORICAL AND THEMATIC RELATIONS FOR THE HUMAN SEMANTIC NETWORK

Before focusing on how categorical and thematic relations might modulate associative recognition memory, it is worth noting why both types of relations appear equally important for human conceptual knowledge (at least for representatives of Western cultures). A body of evidence in support of this comes from research on categorization and memory. A typical experiment on categorization employs matching tasks in which participant is exposed to a triad of items, with one head item relating categorically to the second and thematically – to the third item (sometimes a combination of a related and an unrelated alternative is used as control condition). A participant is then asked to choose out of the two alternatives an item that goes best with the head item according to some criterion. Some research of this type that asked participants to group objects that go together best (Smiley, 1979; Lucariello et al., 1992) suggested that young children prefer predominantly thematic groupings while older children and young adults show a tendency for categorical organization. Yet, this *thematic to taxonomic shift* in categorization preferences was extensively challenged by showing that depending on properties of stimulus material (Greenfield & Scott, 1986), such as salience of thematic relations (Lin & Murphy, 2001), as well as task instructions (Saalbach & Imai, 2007), older children and adults build thematic groupings as much as categorical. Similarly, research on memory (Khan, 1988) also showed that organizing stimulus materials around a specific themes at study (e.g., living on a farm, going to the lake, etc.) leads to equally larger levels of recall as when materials are structured around categories (e.g., vehicles, clothing, animals, etc.).

Furthermore, retrieval of thematic relations from semantic memory does not only happen for strategic reasons, as might be concluded from the above mentioned investigations. In matching task when participants are specifically asked to group the items according to taxonomic categories, conflict trials, that is on which a thematic alternative is presented along with a categorical grouping option (*beer: juice vs. party*), still lead to the preference of the thematic groupings (Lin & Murphy, 2001) and production of more errors than on control trials, i.e. on which a categorical option is presented together with an unrelated item (Gentner & Brem, 1999). Next, whereas categorically related items are considered to be more featurally similar than thematically related ones as discussed before, thematic relations intrude on similarity judgments where participants sometimes rate thematically related associated pairs (e.g. *milk – cow*) as more similar than categorically related unassociated ones (e.g., *milk – lemonade*) (Golonka & Estes, 2009).

Further evidence in this direction originates from experiments employing priming tasts. *Semantic priming paradigm* is a well established procedure for examining access to semantic memory representations (Neely, 1991; Masson, 1995). In tasks of this kind, participants are first shortly exposed to a prime and then to a target word on which a certain task is to be performed, e.g. a lexical decision. A typical observation is shorter response times and higher accuracy associated with targets from related prime-target combinations, e.g., *doctor – nurse*, compared to unrelated, e.g., *bread – nurse*. Such facilitation in the related condition is thought to originate from a rapid spread of activation from a prime conceptual node to a target node in the semantic network (Anderson, 1983; Collins & Quillian, 1969) or from an overlap in prime-target representations under assumption that a target representation is in part pre-activated by a prime (Masson, 1995). Using the priming paradigm, a body of literature reported that both categorical and thematic relations are accessed from the lexical network rapidly and uncontrollably as indicated by comparable priming effects in the two conditions (Hare et al., 2009; Moss, Ostrin, Tyler, & Marslen-Wilson, 1995; Estes & Jones, 2009; Perraudin & Mounoud, 2009; Sass, Sachs, Krach, & Kircher, 2009). In one such investigation, Sachs et al. (2011) found similar behavioural priming effects for categorically and thematically related prime-target pairs in a lexical decision task, e.g., *couch – bed* vs. *couch – pillow*, indicating that both relations were easily accessible in the semantic network. At the same time, different fMRI activations were associated with semantic processing in the two conditions, suggesting that categorical and thematic relations might constitute important alternative ways of structuring conceptual knowledge.

ERPs also provide a reliable measure of semantic memory access. When recorded to the onset of a target in semantic priming paradigms, a negative-going peak, termed *the N400 component*, is observed over centro-parietal sites 300-500ms time post-stimulus (for reviews, see Kutas & Federmeier, 2000, 2011; Lau, Phillips, & Poeppel, 2008). The N400 amplitude is typically reduced with facilitated semantic memory access, yielding an attenuation of negativity for targets from a related compared to an unrelated prime-target condition (C. Brown & Hagoort, 1993; Bentin S. & Hillyard, 1995). Electrophysiological research indicates that both categorical and thematic relations modulate the N400 (Koivisto & Revonsuo, 2001; Deacon et al., 2004) implicating that presence of either relation facilitates access to a target word.

Overall, the above mentioned evidence suggests that thematic and categorical relations are not only employed for strategic reasons in certain experimental tasks but are accessed involuntary and both constitute an important part of human conceptual network.

3.5 HOW MIGHT CATEGORICAL AND THEMATIC RELATIONS MODULATE ASSOCIATIVE RECOGNITION MEMORY? RESEARCH HYPOTHESES

Previous section described categorical and thematic relations, highlighting that, in spite of being important for stucturing semantic knowledge, the two types of relations fundamentally differ in their nature. The relation between categorical coordinates, such as *apple – orange*, is characterized by a high degree of a semantic feature overlap. Such an overlap is not characteristic of conventional thematic relations, as in *milk – cow*, that are rather characterized by a high association strength and integrability of the constituents into a common thematic frame.

The integrative nature of thematic relations makes them interesting from the standpoint of studies on associative recognition reviewed before which show that items encoded as a unified meaningful structure lead to familiarity-supporting memory representations (Opitz & Cornell, 2006; Rhodes & Donaldson, 2007b; Giovanello et al., 2006; Quamme et al., 2007) and a reduced contribution of hippocampus-based recollection during recognition (Bader et al., 2010; Jäger et al., 2006). Whilst the majority of these studies have predominantly employed existing or newly formed compounds as examples of unitized representations, I hypothesize that the holistic nature of thematically related word pairs (Wisniewski & Bassok, 1999) makes them akin to such integrated structures. Of importance here is the possibility that relations of this kind might facilitate the integration of pairs to a greater extent than categorical relations, leading to a change in the extent to which familiarity and recollection are engaged in associative recognition for the two relation types.

Experiment 1 and 2 were therefore set to explore whether categorical and thematic relations between the paired words differentially modulate the episodic processes involved in associative recognition. Both experiments were conducted in Germany with native German participants.

In Experiment 1, participants studied word pairs and subsequently performed an associative recognition test, in which they had to discriminate between old, rearranged, and new pairs. By manipulating the kind of semantic relation between the paired concepts and recording ERPs during the test phase, I aimed to obtain electrophysiological signatures of familiarity and recollection during the associative recognition of the two relation types. In accord with prior research (Greve et al., 2007; Opitz & Cornell, 2006), I hypothesized that word pairs of both relation types should be recognized on the basis of familiarity and recollection. However, the greater capacity for thematic relations to support holistic processing was predicted to lead to an enhanced involvement of familiarity accompanied by a reduced engagement of recollection in associative recognition of thematic compared to categorically related pairs.

Experiment 2 capitalized on the advantages of a forced-choice recognition task over a Y/N associative recognition task as employed in Experiment 1 to further investigate potential differences in familiarity-based recognition for the two relation types. As I shall discuss later in detail, such a task promotes participants' reliance on familiarity during recognition as compared to a Y/N task assumed to rely on recollection (Westerberg et al., 2006; Migo, Montaldi, Norman, Quamme, & Mayes, 2009). I hypothesized that if thematic relations, due to their integrative nature, are more naturally suited for familiarity-based recognition an enhanced contribution of familiarity in this condition should be observed in a task of this kind. Because functional interpretation of the ERPs in a forced-choice task is somewhat obscure, Experiment 2 used behavioral estimates of familiarity and recollection provided by an RK procedure.

CHAPTER 4

CROSS-CULTURAL DIFFERENCES IN CATEGORIZATION AND IMPLICATIONS FOR MEMORY RESEARCH

Previous chapter reviewed the state-of-the-art evidence suggesting that categorical and thematic relations constitute two alternative ways of structuring conceptual knowledge. Cross-cultural research, however, repeatedly indicated that there might be differences in the relative significance of the two relation types for the representatives of different cultures (Chiu, 1972; Gutchess et al., 2006; Ji, Zhang, & Nisbett, 2004; Norenzayan, Smith, & Kim, 2002; Saalbach & Imai, 2007; Unsworth & Pexman, 2005; Varnum, Grossmann, Kitayama, & Nisbett, 2010).

A rather popular idea, originating from research on categorization, is that Westerners, unlike Asians, tend to prioritize categorical relatedness over thematic. Categorization tasks typically require participants to pick several concepts from a larger set that can be grouped according to a certain criterion. Several such studies (Chiu, 1972; Ji et al., 2004; Unsworth & Pexman, 2005) found that Western (American) participants are more likely to group concepts that share a categorical membership than those that share a common theme. Somewhat more controversial evidence suggests an opposite pattern for the East Asians indicating that they might prefer groupings on the basis of thematic relationship (Chiu, 1972; Ji et al., 2004). Following a pioneering work by (Chiu, 1972) conducted with children, (Ji et al., 2004) offered adult participants a *forced-choice categorization task* which asked to select two objects from a triplet that are most closely related (e.g. *policeman – postman – uniform*). The results indicated that Western participants (the USA) tend to group objects on the basis of categorical information (e.g., *policeman – postman*), while East Asians (Chinese) preferred thematic groupings (e.g., *policeman – uniform*).

One of the limitations of the study by Ji and colleagues that undermines the reliability of the results is a very limited set of items consisting of only 10 triplets. In this respect, a study by Unsworth and Pexman (2005) that included 39 triplets appears to be more convincing. The authors employed a forced-choice categorization task that asked participants to determine which of the two pictures go to together best (Figure 4.1). Each triplet allowed for a formation of a categorical or a thematic pair. Whilst failing to replicate a strong thematic-grouping preference for Chinese participants, Unsworth et al. demonstrated that Western participants were more likely to form categorical (e.g., *monkey – tiger*) than thematic groupings. When measuring response times on the same task under speeded conditions, it was found that for Western participants forming categorical groupings took less time than forming thematic groupings, whilst no differences were observed for participants with an East Asian background. A similar observation was made in a priming task (see Section 3.4.3 for more on a priming paradigm) that required participants to evaluate the relatedness of a prime and a target (Unsworth & Pexman, 2005). Response latencies of Western participants were significantly shorter when prime and target were categorically than thematically related. In contrast, no differences were observed in response latencies for East Asian participants. Taken together, the authors interpreted their findings as suggesting that categorical information is more rapidly activated than thematic information in the conceptual system of Westerners, whereas both types of information are equally readily available for East Asians.

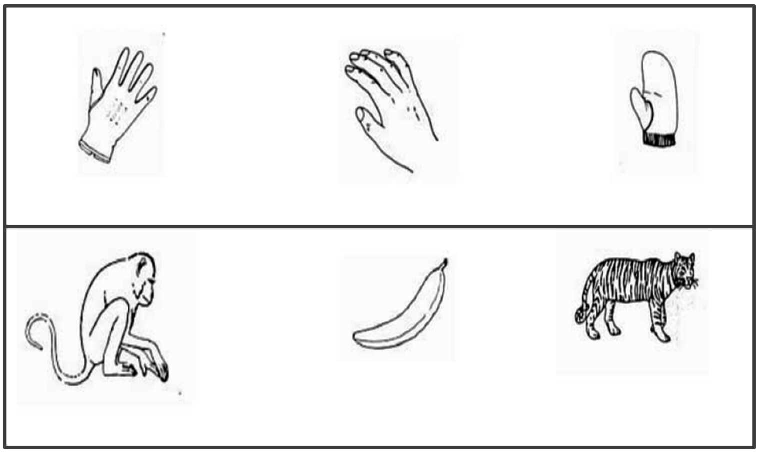


Figure 4.1: Taken from Unsworth and Pexman (2005): sample pictures used in experiments by Unsworth and colleagues. Participants had an option to group either together categorically (*glove – mitten*) or thematically related objects (*glove – hand*).

Findings of cross-cultural differences in categorization tasks were extended to the domain of episodic memory research. Gutchess et al. (2006) investigated whether a bias to categorical grouping observed in categorization tasks in Westerners might affect performance in a free recall task. American and Chinese participants were given two study lists, one of them containing unrelated items and another randomly intermixed categorical associates drawn from five categories, and were subsequently tested in a free recall task. Apart from cultural background, age was also manipulated in the experiment, under the assumption that the categorization-bias effect should be more pronounced in the elderly participants. Elderly Americans were expected to organize information around categories during the free recall more than Chinese participants due to their extensive life-long bias to/experience with categorical grouping strategy. The results indeed did not significantly differ between American and Chinese younger participants, but differences emerged between the groups of the elderly. Whilst having comparable levels of recall, Western elderly participants tended to exploit categorical information as a means to recall items from a previously studied list more frequently than East Asian participants as assessed by the adjusted clustering score.

In spite of the indications that there might be cross-cultural differences in the availability of conceptual relations and reliance on them in different tasks, there is no absolute agreement on whether it is indeed so. Saalbach and Imai (2007) conducted a series of experiments with German and Chinese participants in which they likewise focused on a culturally-determined bias towards a certain type of relationship between the concepts and its effect on task performance. Three of the experiments used forced-choice categorization tasks that imposed different categorization requirements, i.e., group objects that: are most similar to each other; go together best, carry the same bacteria; might have the same property. Overall, all experiments showed a strikingly similar pattern of results in that the preferential use of categorical/thematic groupings was not so much determined by culture as rather by a kind of task requirement. Saalbach and Imai also conducted a priming experiment in which the type of relation between a prime and target was manipulated. The results of this experiment revealed comparable priming effects in the categorical and thematic conditions irrespective of culture. The findings of experiments reported by Saalbach and Imai hint for a universal significance of categorical and thematic relations and that differences observed in various cross-cultural experiments might rather reflect differences on the level of cognitive strategies/processes employed in different tasks by Western and Asian participants rather than on the level of availability of categorical/thematic relations in semantic memory.

Taken together, controversy exists whether there are a cross-cultural differences in making use of semantic relational information. Some data indicate that Western and East Asian participants might differentially prioritize information about the type of conceptual relationships and use it to solve tasks of various kinds (Chiu, 1972; Ji et al., 2004; Unsworth & Pexman, 2005; Gutchess et al., 2006). Specifically, it appears that information about different types of semantic relatedness modulates task-related processes in categorization and memory tasks in Western participants more so than it does in East Asian participants (Unsworth & Pexman, 2005; Gutchess et al., 2006). Other experiments (Saalbach & Imai, 2007) imply universal significance of categorical and thematic relations and their highly similar use in various tasks across cultures.

The aim behind introducing a cross-cultural aspect to the present doctoral project was to further explore putative differences in the way conceptual relationships might guide performance on various tasks in Westerners and East Asians. This was to be achieved by comparing how categorical and thematic relations modulate associative episodic recognition in German and Chinese participants. If categorical and thematic relations are highly relevant for task performance and exploited in similar ways by Asian and Western participants, it can be expected that the type of semantic relatedness will modulate associative recognition memory in Chinese participants in a fashion similar to that of German participants. That is, whereas recognition of both types of relations should be supported by familiarity and recollection, recognition of the thematically related pairs should lead to the enhancement of familiarity and attenuation of recollection in Chinese participants as predicted on the basis of differential nature of categorical and thematic representations (see Section 3.5 describing predictions for German participants). By this the data would support the universal significance view of semantic relations (Saalbach & Imai, 2007). In contrast, if semantic relatedness guides task-related processes in East Asian participants less so than it does in Westerners (Unsworth & Pexman, 2005; Gutchess et al., 2006), no modulation of recognition processes by semantic relation type should be observed in Chinese participants at all.

Experiments 3 and 4, virtually identical to Experiments 1 and 2, were conducted in China with Chinese participants to address these issues.

CHAPTER 5

MATERIALS AND PRE-EXPERIMENATAL RATINGS

The main manipulation in all four associative recognition experiments concerned the type of semantic relation between paired concepts. To accomplish this, a sufficient number of categorically and thematically related pairs, as well as unrelated pairs had to be constructed. Unrelated pairs were to serve as fillers diverting participants' attention from the main relations of interest. This chapter describes the way stimuli were constructed, rated and finally selected for the experiments.

5.1 STIMULUS CONSTRUCTION

The following steps were undertaken to create a sufficient number of word pairs of the three relation types. First, 520 common concrete German nouns were selected and organized into 130 quadruplets (Table 5.1). There were two main categorically-related words in each quadruplet, e.g., *dancer, actor.* which came from diverse categories, such as vegetables, fruits, clothing, professions, natural phenomena, tools, food, beverages, animals, insects, furniture, etc. The third word (word 3) in each quadruplet was categorically related to both main words, e.g., *singer*, thus allowing the construction of two categorical pairs when combined with either of the main words (*dancer – singer; actor – singer*). The fourth word (word 4) in each quadruplet was thematically related to both main words via the same type of thematic relation (functional, spatial, causal, etc), e.g., *stage*, allowing to form two thematically related pairs (*dancer – stage; actor – stage*). Thus, each quadruplet could produce two categorical and two thematic pairs. This was necessary due to the requirement of associative recognition experiments to include rearranged categorical/thematic pairs at test: materials had to enable recombining word pairs and obtaining rearranged pairs of two relation types.

To construct unrelated filler pairs, 130 quadruplets were organized into 65 sets, each consisting of two quadruplets (Table 5.1). It was possible to combine either main word from one quadruplet with word 3 or word 4 from another quadruplet (e.g. *strawberry, orchard*), thus yielding four unrelated word pairs for each quadruplet : e.g. *dancer – strawberry; dancer – orchard; actor – strawberry; actor – orchard*).

SET	QUADRUPLET	MAIN WORD 1	MAIN WORD 2	CATEGORICAL	THEMATIC	UNRELATED	UNRELATED
1	1	DANCER	ACTOR	SINGER	STAGE	STRAWBERRY	ORCHARD
1	2	CHERRY	PLUM	STRAWBERRY	ORCHARD	SINGER	STAGE
2	1	RING	BRACELET	NECKLACE	PRESENT	MEADOW	SUN
2	2	DESERT	PRAIRIE	MEADOW	SUN	NECKLACE	PRESENT

Table 5.1: Experiment 1. Illustration of item construction.

All together, this procedure allowed to create 1040 word pairs: 260 categorical, 260 thematic and 520 unrelated.

5.2 PRE-EXPERIMENTAL RATING PROCEDURE

It was essential to ensure that categorical/thematic/unrelated word pairs genuinely conveyed the designated relationships. Therefore, a questionnaire that required participants to verify the type of relation for each word pair was conducted with native German speakers. In this pre-experimental rating study participants were asked to decide whether the two words are categorically related, thematically related, or unrelated (for detailed information on pre-experimental ratings see Appendix A). All word pairs were assigned to four questionnaire lists such that no word was repeated within the same list and such that all four lists contained different word pairs. Due to the cross-cultural aspect of Experiments 3 and 4, all the stimuli were translated into Mandarin Chinese by a native Chinese speaker and a similar pretest was conducted with native Chinese speakers in China. Word pairs were ultimately selected for the experiment of the basis of cross-cultural interrater agreement on the relation-verification question (see below).

Apart from being asked to verify the type of relation between the paired words, German participants had to evaluate each word pair on three other criteria on a four-point scale: the degree to which the two words could be unitized to form a compound, the amount of shared semantic features, and associative strength (for a similar rating approach see Estes & Jones, 2009; Perraudin & Mounoud, 2009; Wisniewski & Bassok, 1999). The rationale behind including these aspects into the rating study was to examine whether:

- categorical pairs indeed shared more common semantic features than thematic and unrelated ones (Estes & Jones, 2009; Perraudin & Mounoud, 2009; Wisniewski & Bassok, 1999);
- thematic pairings were perceived as more associated than categorical and unrelated (Estes et al., 2011, see Section 3.4.2 addressing the issue of conventional thematic relations);
- thematic pairs might be unitized into compounds more likely than categorical and unrelated pairs (Estes & Jones, 2009).

Though there are databases that provide measures of semantic relatedness and associative strength of word pairs for German, they remain rather limited and did not allow to obtain information for all of the constructed word pairs. Translating the materials and obtaining the required measures from English databases was also problematic as multiple translations were possible for many words. I therefore opted for the pre-experimental rating of the materials, which enabled me to acquire semantic relatedness, associative strength and unitizability ratings for all the word pairs used in the thesis.

Given a fine-grained distinction between the concepts of associative strength and semantic relatedness (see Section 3.4.2), I tried to avoid contamination of semantic relatedness ratings by associative strength ones by creating two versions of the questionnaire. Each of them included a relation-verification question and a unitization question. Apart from that, version 1 asked participants to evaluate each word pair on semantic relatedness, whilst version 2 queried the associative strength of word pairs. Half of the participants received the questionnaire in version 1, and the other half received it in version 2.

5.3 PRE-EXPERIMENTAL RATING EVALUATION AND MATERIAL SELECTION

One hundred seventy six native German and 206 native Chinese speakers, took part in the pre-experimental rating of materials. Materials for the experiment were to be selected on the basis of the relation-verification question in order to assure that the constructed word-pairs were perceived as carrying the designated relations by participants in both cultures. Therefore, for each word pair, the proportion of correct classifications (percentage of responses when participants indeed attributed the designated type of relation to the pair) and misclassifications (proportion of cases when participants attributed to the word pair the type of relation other than the designated one) were computed for each word pair. As it was critical to assure that the obtained answers on the relation-verification question indeed represented an average opinion on which relation was connecting words in a pair (categorical, thematic, unrelated), those participants who deviated more that 2*SD* from the mean number of misclassifications on the relation-evaluation task in the respective culture were excluded from further analyses (German: $n = 9$; Chinese: $n = 14$). The remaining 167 German participants were on average 22 years old (ranging from 18 to 36 y.o.). One hundred and ninety two Chinese participants whose data were included into the analyses were on average

21 years old (ranging from 17 to 24 years).

For the experiment, I selected 45 sets out of the total 65 sets evaluated (which resulted in a formation of 720 word pairs: 180 categorical, 180 thematic and 360 unrelated). A set was selected if all sixteen word pairs that each set allowed to form were confirmed to have the corresponding relations by more than 50% of participants in at least one of the cultures. These sets are listed in Appendix B. In German version of the materials, words were 3 – 14 letters in length (*M* = 6.5, *SD* = 2.2) and had a frequency ranging from 1 to 314 occurencies per million (*M* = 24.5, *SD* = 38.8) according to CELEX database (Baayen, Piepenbrock, & Rijn, 1993). Chinese words were 1 to 4 characters in length (*M* = 2.2, *SD* = .4), with a frequency of 5 to 3445 occurencies per 20 million Chinese characters according to Beihang dictionary (*M* = 180.7, *SD* = 376) (Liu & Liang, 1989). For the selected materials, the inter-rater agreement for relation verification question was 90.3% for categorical relation, 90.1% for thematic and 95.6% for unrelated among German participants. Among Chinese participants, in 86.4% of cases participants agreed that pairs initially designated as categorical indeed carried this type of relation. Interrater agreement was 76.9% for thematic and 92.7% for unrelated items. Such high interannotator agreement suggests that the type of relationship between the word pairs was plausible and easily identifiable warranting inclusion of these word pairs into recognition experiments.

5.4 ASSOCIATIVE STRENGTH, SEMANTIC RELATEDNESS AND UNITIZATION RATINGS

Based on the ratings of German participants, associative strength, semantic relatedness and unitization scores were then computed for every word pair to be included into the experiments (separate mean values for categorical, thematic and unrelated conditions are provided in Table 5.4). Three separate Welch tests were conducted to investigate the effect of Relation (categorical, thematic, unrelated) on the associative strength, semantic relatedness and unitization scores revealing that Relation modulated each type of rating, all *p*-values $< .01$ (Welch test was chosen to appropriately deal with unbalanced sample sizes: there were more items in the unrelated condition than in each of the related ones). Post-hoc comparisons using Games-Howell procedure indicated that both categorical and thematic word pairs were judged more related, more associated and more unitizable than unrelated, all *p*-values $< .01$. As expected, categorical pairs were judged more semantically related than thematic, *p*-values $< .001$, confirming the critical aspect defining categorical relatedness is the number of shared semantic features (Estes & Jones, 2009; Perraudin & Mounoud, 2009; Wisniewski & Bassok, 1999). Thematic pairs in turn were perceived as more unitizable than categorical, *p*-values $< .001$, and tended to be more associated than categorical, $p = .089$. As described in Section 3.4.2, both categorically and thematically related items can be associated. Yet, because predominantly conventional thematic relationships (i.e., typical relations between frequently co-occurring items, Section 3.4.2) were employed in the study, it is plausible that thematic condition was perceived as slightly more associated than categorical. Higher unitizability of thematically related pairs compared to the two other conditions dictated the choice of encoding procedure in all four associative recogntion experiments. As I was interested in the effect of semantic relation on recognition of paired associates and not on recognition of single-unit compounds, study phases employed a single item mental imagery procedure in order to prevent strategic compound formation in the thematic condition at encoding (see next chapter for the detailed explanation of the rationale behind this encoding task).

	Semantic Relatedness	Associative Strength	Unitization
Categorical	1.84 (.03)	2.21 (.04)	3.29 (.03)
Thematic	3.36 (.02)	2.11 (.04)	2.45 (.05)
Unrelated	3.91 (.01)	3.87 (.01)	3.84 (.01)

Lower numbers reflect higher rating scores.

Table 5.2: Material information. Mean semantic relatedness, associative strength and unitization scores (standard error) revealed by German pre-experimental ratings.

5.5 CONCLUDING REMARKS

The procedure described in this chapter allowed me to create a sufficient number of categorically/thematically related and unrelated pairs. Pre-experimental ratings conducted in Germany and in China enabled to verify the type of relation between the paired concepts and select those which were perceived as carrying the designated relations. Additional ratings of semantic relatedness, associative strength and unitizability collected in Germany, confirmed that materials from the selected set possessed the characteristics appropriate to each type of relationship. Categorically related pairs were marked by a higher semantic feature overlap than the two other relation types. Thematically related pairs were perceived as more unitizable and tended to be judged as more associated. The results of the rating studies show that the selected word pairs constitued an optimal set for investigating the effect of semantic structure of associative recognition memory and conducting cross-cultural experiments.

CHAPTER 6

EXPERIMENT 1

6.1 INTRODUCTION

Experiment 1 was designed to directly test the possibility that categorical and thematic relatedness between the paired words might differentially recruit familiarity and recollection during associative recognition. To this end, I asked participants to learn a list of word pairs some of which were unrelated (filler items) and others – related categorically or thematically- by performing a mental imagery task. Participants then took a standard associative recognition test in which for every word pair they had to decide whether the two words were previously studied in the same combination (old), were studied but in different combinations (rearranged), or were completely new. Building on prior research (Greve et al., 2007; Opitz & Cornell, 2006), categorical and thematic relations were both predicted to engage familiarity and recollection in associative recognition. However, as thematic relation arguably supports integrative processing of the stimuli (Estes et al., 2011; Markman & Wisniewski, 1997) and integrative processing, in turn, is known to promote familiarity- and reduce recollection-based recognition (Opitz & Cornell, 2006; Quamme et al., 2007; Bader et al., 2010; Jäger et al., 2006), quantitative differences in the engagement of the two processes were expected to be observed between categorical and thematic conditions.

ERPs were recorded during the experiment to obtain an objective measure of the online engagement of these processes (see Section 1.3.2, Friedman & Johnson, 2000; Mecklinger & Jäger, 2009). After the appropriate post-processing (described in Section 6.2.5), it was possible to quantify the engagement of mnemonic processes by comparing test ERPs of correctly responded to old word pairs and correctly rejected new ones, and to dissociate between familiarity and recollection-based recognition owing to distinct spatiotemporal patterns of their associated neural activity: the early frontal and late parietal old/new effects, respectively. The patterns of results obtained in the categorical and thematic conditions were then compared on qualitative and quantitative dimensions. The key prediction was the enhancement of the familiarity-related early frontal old/new effect and an attenuation of recollection-related late parietal old/new effect in the thematic compared to the categorical condition.

Apart from the main experimental question, several other points were addressed in a series of additional analyses:

- First, ERPs associated with accurate recognition of the unrelated filler word pairs were analyzed to investigate whether the absence of semantic relatedness might yield a notably different pattern of results. Keeping in line with previous research (D. I. Donaldson & Rugg, 1998), it was expected that when to-be-remembered words are arbitrarily paired at study, their retrieval should be primarily supported by recollection. Unrelated filler analyses thus served to assure that the presence of any early frontal old/new effect in the related conditions should be indeed attributed to the effect of semantic relatedness and not to the specifics of experimental procedure.

- Second, in light of the debate about functional significance of the early frontal old/new effect, the possibility that this effect might be contaminated by simultaneously emerging semantic priming effects reflected in the N400 was examined (Voss & Federmeier, 2011). To avoid a confound with episodic memory effects, ERPs elicited only by correctly rejected new word pairs in the categorical, thematic and unrelated conditions were contrasted. Such a contrast allowed me to tap into the semantic N400 – an ERP component sensitive to semantic memory access. If a modulation of the N400 by relation would be observed on the frontal sites in the same time window as the early frontal old-new effect, then it might be reasonable to doubt the functional purity of the early frontal old/new. In this case it might reflect a mixture of episodic and semantic memory processes.

- Third, to find out whether (potential) differences in engagement of the associative recognition processes in the categorical and thematic conditions might be in part attributed to differences emerging at the encoding, study-phase ERPs were compared for word pairs subsequently correctly identified as old. Of particular interest here was the N400 component due to its sensitivity to the demands posed by mental imagery. Prior research indicated that concepts that can be visualized relatively easy show a more negative N400 than words with a low imagery value (Nittono, Suehiro, & Hori, 2002; West, 2000). Because processing categorically related concepts seems to rely on perceptual processing more than thematically related concepts (see Section 3.4.1 Kalenine et al., 2009; Kotz et al., 2002; Sachs et al., 2008), mental imagery could have been a more engaging task for the items of this type. If so, more negative N400 should be expected for the categorical condition. Finding an indication of the task-related differences at encoding would then mean that they should be carefully taken into account when interpreting any observed differences in the engagement of mnemonic processes at retrieval.

Taken together these three additional analyses were employed to control the factors, other than the type of semantic relation per se, that could have impacted processes engaged in associative recognition of categorical and thematic relations.

6.2 METHOD

6.2.1 PARTICIPANTS

Eighteen participants, none of whom were involved in the pre-experimental rating of materials, took part in Experiment 1 for course credit or payment. Informed consent was collected as appropriate. The data from two participants was discarded due to chance performance at test for old or new items in one of the conditions of interest (categorical or thematic) and, as a consequence, a very low number of artifact-free trials left for the ERP analysis. The remaining 16 participants (11 female) were on average 23 years old (age range: 19 to 26 years). All participants in Experiment 1 and in Experiment 2 were native German speakers, right-handed and had normal or corrected to normal vision.

6.2.2 MATERIALS

All 45 stimulus sets selected for the experiment (Chapter 5; see Appendix B for a list of word pairs) were pseudo-randomly assigned to 9 item groups. The assignment of item groups to relation condition (categorical/thematic vs. unrelated filler) and test condition (type: old, rearranged, new) was counterbalanced. Categorical, thematic and unrelated pairs were pseudo-randomly intermixed both in the study and test session, such that word pairs in the same relation-condition could not appear on more than two subsequent trials. Participants took part in two study – test sessions. In each experimental session, a study list comprised 40 categorical, 40 thematic and 40 unrelated pairs. A test list comprised 60 old, 60 rearranged and 60 new pairs (20 pairs of each relation in each item type category). Even though the same words were used in both sessions, the way they were paired was different across sessions, e.g., pairs that were assigned to the categorical condition in session 1, appeared in the thematic or unrelated condition in session 2, etc.

6.2.3 DESIGN AND PROCEDURE

Experiment 1 was implemented using E-prime software. Stimuli were presented on a 19” monitor (Courier New, font size 22) in black on a white background. A response box (RB Series by Cedrus) was used as an input device.

During the study, participants memorized word pairs (categorical, thematic, and unrelated) presented word by word in the context of a single item imagery task. By introducing an item imagery task and a sequential presentation, followed by a task to compare the clarity of the mental images, I aimed to assure that participants did not form compounds from the presented word pairs but rather encoded them as separate paired items. I assumed that such a presentation of stimuli at encoding would allow to tap into the effects of semantic relations while controlling for the effects of strategic item-unitization.

As Figure 6.1 shows, each trial began with a fixation cross presented for 1000ms, followed by a blank screen for 250ms. After that the first word from a pair appeared for 400ms. A blank screen (1000ms) followed during which participants had to mentally visualize the named object. The procedure was then repeated for the second partner word. After that, a question mark appeared on the screen prompting participants to compare the two mental images and indicate by a button press whether the first or second image was clearer, or both were equally clear (maximum duration 2000ms). An inter-trial interval was 100ms. Study phase was subdivided into 4 blocks, separated by self-paced pauses. After the study phase, a visual search distracter task was performed on paper for 5 minutes to prevent rehearsal of the materials.

Test phase immediately followed the distracter task (Figure 6.1). At test, each trial started with a 1000ms fixation cross, followed by a 500ms blank screen, after which a word pair was presented for 800ms, with words presented on the same level, one to the left and another one to right of the center. Then a response display appeared (max. duration 2200ms) during which participants were to endorse the word pair as either old, rearranged, or new by pressing one of the three respective response buttons with point, middle and ring finger of their right hand. After providing their response, participants had to rate their response confidence (max. 1500ms) as "sure" or "unsure" with point/middle finger of their left hand. A 100ms inter-trial-interval followed. Test phase consisted of 4 blocks, separated by self-paced breaks. Assignment of response types (recognition/confidence judgment) to hands was counterbalanced across participants. Each participant went through two study-test sessions, with a gap of approximately one week between the sessions.

6.2.4 DATA AQUISITION

EEG was recorded from 58 silver/silver-chloride electrodes embedded in an elastic cap (Easycap) according to the extended International 10–20 system (American Encephalographic Society, 1994). Other two electrodes were placed at each mastoid. EOG (electrooculogram or eye-related activity) was recorded from four electrodes located above and below the right eye and on the outer canthi of both eyes. Data were acquired with an amplifier bandpass from DC to 70 Hz and digitalized at a sampling rate of 500 Hz with a resolution of 16-bit. Electrode impedances were kept below 10 k Ω. EEG was recorded using a left-mastoid reference but all EEG channels were offline re-referenced to linked mastoids. Further offline processing included filtering with a low-pass set to 30Hz and splitting the data into individual epochs from 100ms pre-stimulus to 1000ms post-stimulus. Epochs containing eye artifacts were corrected using the procedure suggested by Gratton, Coles, and Donchin (1983), while trials containing other artifacts (whenever

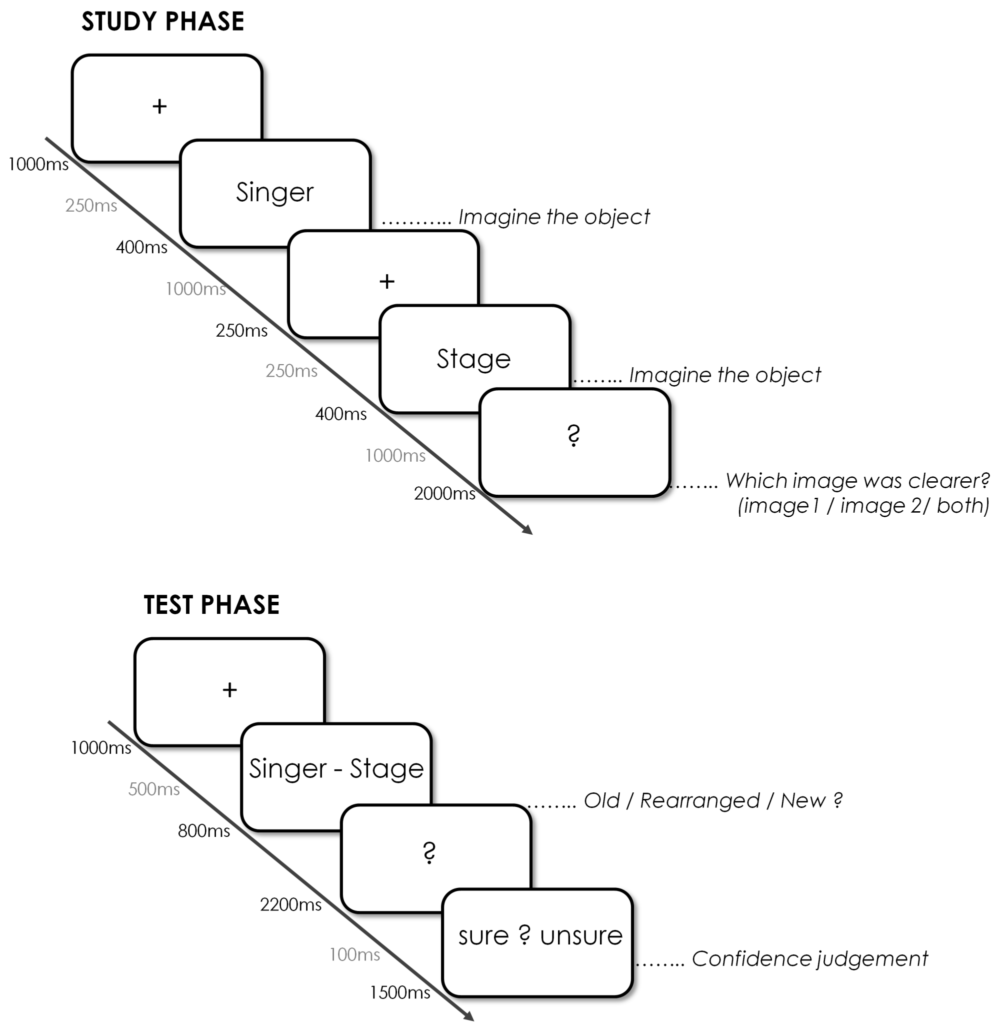


Figure 6.1: Experiment 1. Illustration of the experimental procedure. The upper pannel shows a trial procedure during the study phase; the lower pannel depicts a trial procedure during the test phase.

standard deviation in a 200ms time interval exceeded 30 μV in either Cz or any of EOG channels) were rejected. After eliminating artifact containing trials, mean averages were computed for the conditions of interest for each participant at all recording sites. The mean number of artifact-free trials contributing to the analysis of test-phase ERPs of old and new pairs was 25 and 28 in the categorical condition, and 21 and 27 in the thematic condition. For the study phase, only word pairs subsequently correctly recognized as old contributed to grand averages in the categorical and thematic conditions, mean number 26 and 22, respectively. For presentation purposes, the data was further filtered with a low-pass filter set to 12 Hz.

6.2.5 DATA ANALYSIS

To evaluate behavioral indices of recognition memory, several measures were obtained (computed and corrected according to Snodgrass & Corwin, 1988). *Hit-rate* was computed as probability of an old response to old word pairs, Hit-rate = (#Hits + .5) / (#Old + 1). Accordingly, *correct rejection (CR)* rate was defined as probability of a new judgment to new word pairs, CR-rate = (#CR + .5) / (#New +1). *False alarm (FA) rate* was calculated for rearranged pairs incorrectly attracting old judgment, FA_rearranged = (#FA_rearranged_endorsed_as_old + .5) / (#Rearranged + 1) and for new pairs erroneously endorsed as old, FA_new = (#FA_new_endorsed_as_old + .5) / (#New + 1). Furthermore, indices of participants' ability to discriminate between old/new and old/rearranged pairs, i.e. *old/new and associative Pr scores*, were computed. Old/new Pr score was computed by subtracting false alarms to new pairs endorsed as old from the hit rate, and associative Pr was derived by subtracting false alarms to rearranged items classified as old from the hit-rate.

Repeated measures analyses of variance (ANOVAs) were employed for the inferential statistics. For all ANOVAs, F-values associated with more than 1 degree of freedom in the nominator have been corrected for sphericity violations with Greenhouse-Geisser procedure. Uncorrected degrees of freedom and corrected p-values are reported. Estimates of effect size (η^2) are provided where necessary. Probability values of the subsidiary t-tests were adjusted using Holm-Bonferroni correction (Holm, 1979). For all analyses, the significance level was set to .05.

As recombined pairs were only included in the test phase to assure that participants rely on associative recognition and do not make endorse word pairs as old solely on the basis of item memory, these pairs were not included in the analyses of the ERP data (for a similar approach, see Bader et al., 2010; Greve et al., 2007; Rhodes & Donaldson, 2007a; Wiegand, Bader, & Mecklinger, 2011). However, rearranged pairs were included into the behavioral analyses to examine whether participants could indeed discriminate between old and rearranged pairs.

The early old/new effect, the putative correlate of familiarity, is typically observed bilaterally on frontal electrodes around 300 – 600ms post stimulus. In contrast, the late parietal old/new effect, associated with recollection, has a left parietal maximum around 500 – 800ms post stimulus. Given these topographic characteristics, the data recorded from the following 8 electrodes were analyzed: superior and inferior left-frontal (F1, F3), right-frontal (F2, F4), left-parietal (P1, P3) and right-parietal (P2, P4) (Figure 6.3.2 C). In accordance with temporal characteristics of the effects, 350 – 550ms and 550 - 750ms windows were selected. Mean amplitude measures were then obtained for each condition by computing mean voltages in the mentioned time windows recorded at each of the eight electrodes. For topographic analyses, the data was normalized using the vector-scaling procedure as suggested by McCarthy and Wood (1985) (see also Picton et al. (2000) for a review).

When analyzing study phase ERPs, additionally to the above mentioned ROIs, two regions of interest along the central line were included (electrodes C3,C1 and C2,C4) in accord with a centro-parietal and sometimes more anterior distribution of the N400 (Kutas & Federmeier, 2000). A time window of 300-500ms after the onset of the second word in a pair was chosen in line with previous literature (Kutas & Federmeier, 2000).

6.3 RESULTS

6.3.1 BEHAVIOURAL RESULTS

Table 6.3.1 summarizes hit rates, correct rejection(CR) rates, and false alarm (FA) rates separately for the categorical and thematic conditions[1]. It also reports two types of Pr scores indexing old/new and associative discriminability.

	Hit rate	CR rate	FA new	FA rear	Pr old-new	Pr associative	RT	
							Hit old	CR
Categorical	.75 (.03)	.87 (.02)	.04 (.01)	.43 (.03)	.72 (.03)	.32 (.03)	1557 (49)	1446 (41)
Thematic	.64 (.04)	.83 (.03)	.04 (.01)	.30 (.02)	.60 (.05)	.34 (.05)	1613 (60)	1461 (38)

Table 6.1: Experiment 1. Behavioural results. Mean hit rate, correct rejection rate, corresponding mean reaction times, and two types of Pr scores indexing old-new and associative discriminability (standard error). Provided are also false alarm rates to new (FA new) and rearranged (FA rear) word pairs incorrectly endorsed as old.

The pattern of results shows higher recognition accuracy in the categorical than thematic condition for both old and new pairs, as well as overall higher accuracy for new than old items. Two-way ANOVA with the factors Relation (categorical, thematic) and Type (Hit, CR) yielded a main effect of Relation, $F(1,15) = 29.369$, $p < .01$, a main effect of Type, $F(1,15) = 17$, $p < .01$, but no significant interaction between Relation and Type, $F(1,15) = 2.402$, $p > .14$. Pairwise comparisons of the discrimination old/new and associative Pr indices between categorical and thematic conditions, revealed better old/new discrimination following categorical than thematic pairs, $t(15) = 4.058$, $p < .01$, but no significant differences in associative discriminability, $p > .76$. The latter result was driven by a higher FA rate in the rearranged categorical than thematic condition, $t(15) = 4.051$, $p < .01$, which suggests that participants had more difficulty rejecting rearranged items as unseen if they were connected by a categorical relationship.

[1]As mentioned before, participants went through two study-test sessions which took place on separate days. To examine whether testing sessions differed with respect to mnemonic performance, a three-way-ANOVA with factors Testing Session (session 1, session 2), Relation (categorical, thematic) and Type (old, new) was conducted on the accuracy data, and separate two-way ANOVAs with factors Testing Session (session 1, session 2) and Relation (categorical, thematic) were performed on the overall and associative Pr-scores. As none of the analyses revealed an effect of Testing Session or interactions involving this factor, all p-values $> .05$, all further analyses were conducted on the data collapsed across the two sessions.

The pattern of results for accuracy data is mirrored in the reaction times data (Table 6.3.1). Reaction times for the categorical pairs were faster than for the thematic pairs, and faster for new compared to old pairs. An ANOVA with the factors Relation (categorical, thematic) and Type (old, new) revealed a main effect of Relation, $F(1,15) = 7.742$, $p = .01$, as well as a main effect of Type, $F(1,15) = 9.173$, $p < .01$, but no significant Relation by Type interaction, $F(1,15) = 1.141$, $p = .30$.

Additionally, confidence ratings that followed correct responses to old and new items were compared for the categorical and thematic conditions to test whether differences in memory performance can be explained by simple changes in confidence strength. Confidence ratings required a binary response (either "sure" or "unsure"), meaning that the probability of high-confidence responses was conditional on the probability of low-confidence responses. Therefore, only "sure" responses were analysed. Probabilities of a "sure" response to correct old and new judgments in the categorical condition [mean values with standard error of the mean are .93 (.02) and .86 (.03), respectively] were compared with in the thematic one [mean values with standard error of the mean are .92 (0.02) and .82 (0.04), respectively]. An ANOVA with factors Relation (categorical, thematic) and Type (hit, correct rejection) revealed only a main effect of Type, $F(1,15) = 5.564$ $p = .03$, suggesting that, for correct responses, participants felt more confident to accept items as old rather than reject them as new. No main effect of Relation and no interaction with this factor were found, all p-values $> .12$, indicating that better memory performance for the categorical than thematic relation cannot be attributed to differences in the confidence of responses.

6.3.2 ERP RESULTS

Grand average ERP waveforms at electrodes F1, F2, F3, F4 and P1, P2, P3, P4 separated for the categorical and thematic conditions are shown in Figure 6.3.2. Upon visual inspection, there appear to be robust differences in the pattern of results for the two relations: while old/new differences are pronounced in the early time window at frontal electrodes in both conditions, old/new differences at parietal sites in the late time window are present only for the categorical relation (for a view of the old/new waveforms in the categorical and thematic conditions from 46 electrodes see Figures D.1 and D.2 in Appendix D).

To check statistical significance of the visually observed pattern, separate ANOVAs were conducted on the data from the early and late time windows with the factors Relation (categorical, thematic), Type (old, new), Location (frontal, parietal), Hemisphere (right, left) and Site (inferior, superior). Only significant effects involving factors Relation and Type are reported.

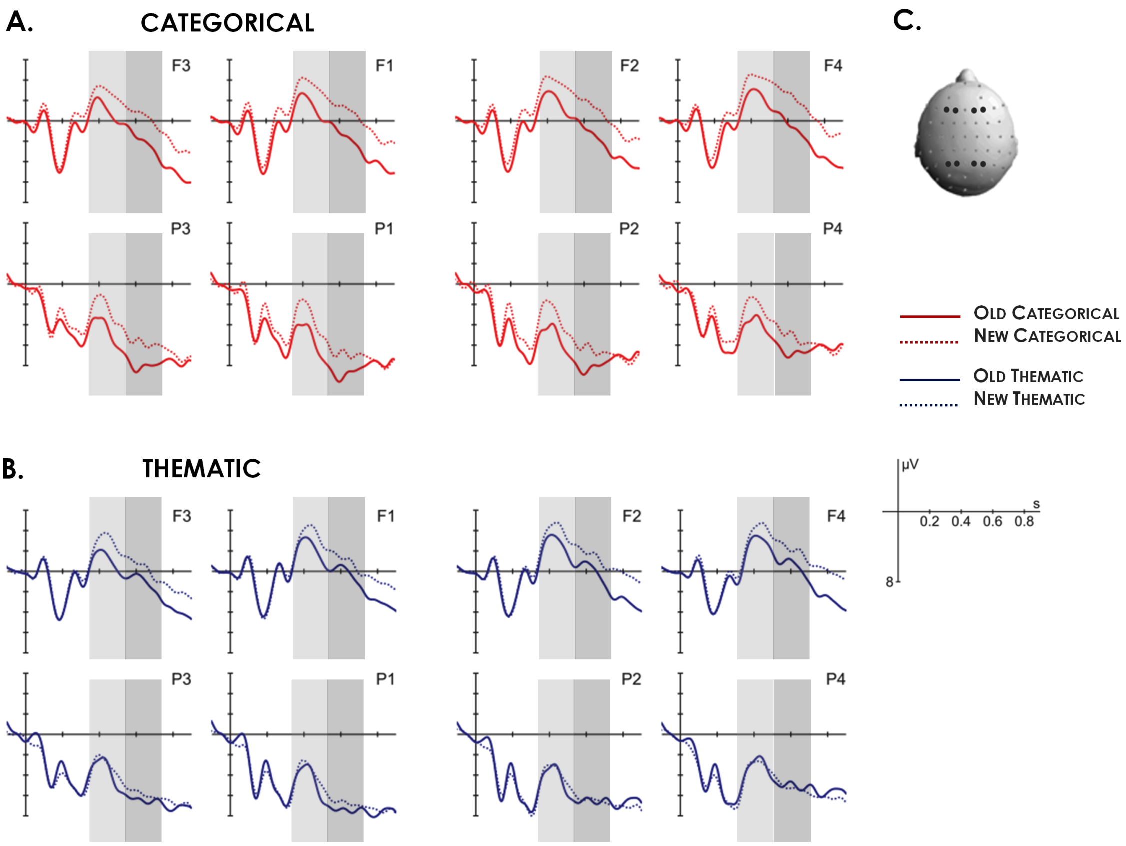


Figure 6.2: Experiment 1. Old/new effects observed during the test phase. (A) depicts grand average ERPs elicited by correct old and new responses in the categorical condition. (B) depicts grand average ERPs elicited by correct old and new responses in the thematic condition. (C) highlights the sites of electrodes (F3, F1, F2, F4 and P3, P1, P2, P4) included into analyses of the early and late old/-new effects as viewed from above.

6.3.2.1 ANALYSES OF THE ERPs FROM THE EARLY TIME WINDOW

The initial ANOVA revealed a main effect of Type, $F(1,15) = 24.328$, $p < .001$, a five-way interaction between factors Relation, Type, Location, Hemisphere and Site, $F(1,15) = 5.321$, $p = .04$, and a three-way interaction between factors Relation, Location and Site, $F(1,15) = 7.513$, $p = .02$. Next, separate ANOVAs for the frontal and parietal locations were conducted. At frontal locations, there was a main effect of Type, $F(1,15) = 35.137$, $p < .001$, and a four-way interaction between Relation, Type, Hemisphere and Site, $F(1,15) = 4.730$, $p = .05$. To resolve the latter interaction, separate analyses were conducted at each frontal electrode for the categorical and thematic conditions as a function of Type. There was an effect of Type at each of the four electrodes for both categorical and thematic items, all p-values $< .01$ (with larger effect size especially on the right frontal sites for the categorical relation, F2: $\eta^2 = .621$, F4: $\eta^2 = .664$ than thematic, F2: $\eta^2 = .431$, F4: $\eta^2 = .474$), suggesting that ERP waveforms to old items were reliably different from those to new items on all frontal sites irrespective of relationship condition. That the ERP correlate of familiarity was equally present in both relation conditions was confirmed by directly comparing the magnitude of the old/new effects ("old minus new") averaged across the frontal electrodes (Figure

6.3.2.1)), $t(15) = .879$, $p = .39$.

At parietal locations in this time window, there was a main effect of Type, $F(1, 15) = 10.034$, $p < .01$, Relation by Type interaction was only marginally significant, $F(1, 15) = 3.161$, $p = .10$, and other interactions involving either of the factors of interest failed to reach significance, all p-values $> .47$. As Fig. 1A indicates the presence of parietally distributed old/new effect in the categorical but not in the thematic condition, subsidiary paired t-tests were employed to test this pattern statistically. The results confirmed the visual observation of old/new differences in the categorical, $t(15) = 4.177$, $p < .01$, but not in the thematic condition, $t(15) = .681$, $p = .50$. Directly comparing effect magnitudes at parietal electrodes (Figure 6.3.2.1) also suggested a larger effect in the categorical than thematic condition, $t(15) = 1.778$, $p = .05$ (one-tailed).

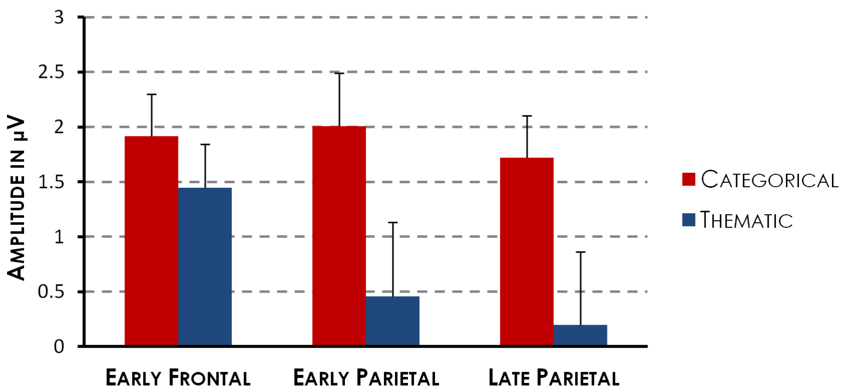


Figure 6.3: Experiment 1. Mean magnitudes of the early frontal old/new effect (averaged over four frontal electrodes), the early parietal old/new effect (averaged over four parietal alelectrodes) and the late parietal old/new effect (averaged over four parietal electrodes) separately for the categorical and thematic conditions.

6.3.2.2 ANALYSES OF THE ERPs FROM THE LATE TIME WINDOW

The initial analysis in this time window revealed a main effect of Type, $F(1, 15) = 22.638$, $p = .001$, a marginally significant Relation by Type interaction, $F(1, 15) = 3.888$, $p = .07$, and a marginally significant four-way interaction between the factors Relation, Type, Location and Site, $F(1, 15) = 4.229$, $p = .06$. Further, separate ANOVAs for frontal and parietal locations with the factors Relation, Type, Hemisphere and Site were conducted. At frontal locations, all old and new ERPs diverged from one another regardless of Relation condition, as manifested by a main effect of Type, $F(1, 15) = 9.192$, $p < .01$. There was no effect and no interactions involving the factor Relation. In contrast, at parietal sites a significant Relation by Type interaction was found, $F(1,15) = 5.003$, $p = .04$. Paired contrasts of the data collapsed across the factors Hemisphere and Site, revealed a significant old/new effect in the categorical, $t(15) = 4.467$, $p < .001$, but not in the thematic condition, $t(15) = .296$, $p = .77$. Figure 6.3.2.1 shows that "old minus new" voltage differences averaged across all parietal sites were larger in the categorical than thematic condition, $t(15) = 2.237$, $p = .04$.

6.3.2.3 TOPOGRAPHIC ANALYSES

Topographic analyses were conducted to explore whether there was a qualitative difference in the pattern of neural generators engaged in recognition processes over time for the two relation conditions (Figure 6.3.2.3). These analyses were performed on vector-scaled difference waveforms (old minus new) from the 350–550 and 550–750 ms windows averaged across inferior and superior sites of the left and right hemispheres on frontal and parietal locations. An ANOVA with the factors Window (early, late), Relation (categorical, thematic), Location (frontal, parietal) and Hemisphere (right, left) revealed a significant four-way interaction between the factors Window, Relation, Location and Hemisphere, $F(1, 15) = 10.674$, $p < .01$, pointing to different spatiotemporal characteristics of neural processes contributing to successful recognition of the categorical and thematic relations. Importantly, topographic differences do not appear to be primarily driven by the earlier recognition processes, as spatial distributions of the early old/new effects did not statistically differ between the two conditions: ANOVA with the factors Relation, Location and Hemisphere conducted on the data from the early time window did not yield any main effect of Relation or other interactions involving this factor, all p-values $> .11$. A Relation by Location interaction that approached significance, $F(1, 15) = 2.841$, $p = .11$, nonetheless points to the presence of the additional posterior effect in the categorical condition. In contrast, the scalp distribution of the late effects differed for the two relations as suggested by a three-way interaction between Relation, Location and Hemisphere, $F(1, 15) = 6.227$, $p = .03$, indicating that different neural generators contributed to recognition of the two relations from 500ms onwards.

In addition, as the analysis of the ERP waveforms revealed reliable old/new differences in the categorical condition in the early time window at both frontal and parietal electrodes and in the late time window at parietal electrodes, a separate analysis was conducted on the vector-scaled difference waveforms (old minus new) from the categorical condition to determine whether scalp distributions of these old/new effects differed as a function of time. Three-way ANOVA with factors Window (early, late), Location (frontal, parietal) and Hemisphere (left, right) yielded a marginally significant Window by Location interaction, $F(1, 15) = 3.538$, $p = .08$, thus implying that different processes were engaged in associative recognition of the of the categorical pairs at different temporal stages. To determine whether the early old/new differences in the categorical condition at posterior sites were driven by the early onsetting recollection, we compared spatial characteristics of the early and late old/new effects at posterior sites by conducting an ANOVA with factors Window (early, late), Hemisphere (left, right) and Site (inferior, superior). The analysis revealed a significant Window by Site interaction, $F(1, 15) = 11.773$, $p < .01$, indicating that another process, distinct from recollection, could have contributed to the early parietal old/new effect in the categorical condition.

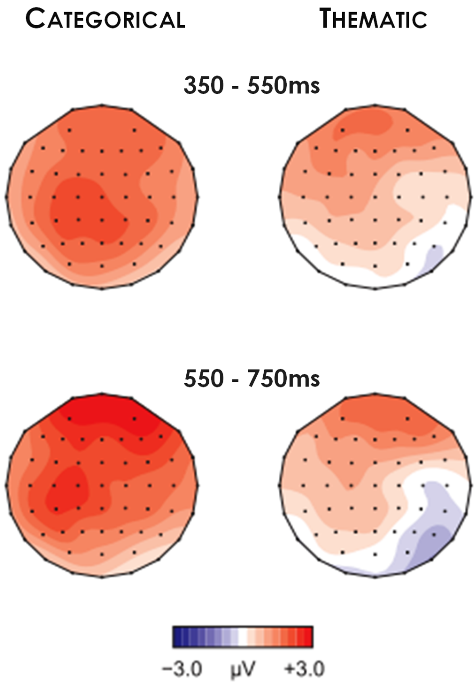


Figure 6.4: Experiment 1. Topographic maps showing the distribution of the early (350-550) and late (550-750) old-new effects separately for the categorical and thematic conditions.

6.3.3 ADDITIONAL ANALYSES

The pattern of the above described ERP results indicates the presence of the early frontal old/new effect in both categorical and thematic conditions, and presence the late parietal old/new effect in the categorical condition only. Here I describe several additional analyses which were performed to provide further insights into the functional significance of the observed effects as well as factors that could have contributed to the emergence of these effects.

6.3.3.1 OLD/NEW EFFECTS FOR UNRELATED WORD PAIRS

As described in Chapter 3, associative recognition of arbitrary word pairs predominantly relies on recollection as indexed by the late-parietal old/new effect (D. I. Donaldson & Rugg, 1998). Therefore, it is tempting to attribute the early frontal old/new effects observed in both related conditions to the effect of pre-experimental semantic relatedness on associative recognition. However, it is also possible that the observed effects are simply an artifact of the particular experimental procedure employed. To discriminate between the two possibilities, unrelated filler items were analyzed. If the early frontal old/new effect would be observed in this condition, this would serve as an indicaion that the early effects in the categorical and thematic conditions cannot be explained solely by the effect of semantic relatedness on associative recognition.

To this end, the data from three participants had to be discarded from this analysis due to an insufficient number of trials for unrelated hits (i.e., 10 or less trials). For the remaining 13 participants, mean Hit and CR rates (with standard error) were M = .45 (.04) and M = .75 (.03), respectively, suggesting that participants had more difficulties in correctly recognizing studied pairs than in identifying new ones, $t(12)=5.604$, $p < .01$, as was also the case in the related conditions. Grand average ERP waveforms for unrelated hits and correct rejections (mean number of trials was 16 and 26), along with topographic distribution of the early and late old/new effects are presented in Figure 6.3.3.1 (see also Figure D.3 in Appendix D for an extended view). Whilst verbal inspection indicates a degree of divergence between new and old items in the early time window, the differences in the late time window were notably greater and characterized by more positive-going waveforms for correctly recognized old than correctly rejected new items at parietal sites. Separate ANOVAs, conducted on the data from the early and late time windows, 350-550 ms and 550-750 ms, respectively, with factors Type, Location, Hemisphere and Site, revealed no main effect and no interactions with factor Type in the early time window but a marginally significant four-way interaction in the late time window, $F(1,12) = 7.513$, $p = .052$, a marginally significant effect of Type, $F(1,12) = 3.675$, $p = .08$, as well as a marginally significant Type by Location by Hemisphere interaction, $F(1,12) = 3.601$, $p = .08$. Resolving the four-way interaction by conducting paired contrasts on the data of the late time window revealed that hits and correct rejections did not significantly differ over the frontal sites, all p-values $> .1$, but differed at P4, $t(12) = 2.409$, $p = .03$, and tended to diverge on P3, $t(12)=2.141$, $p = .05$ (one-tailed).

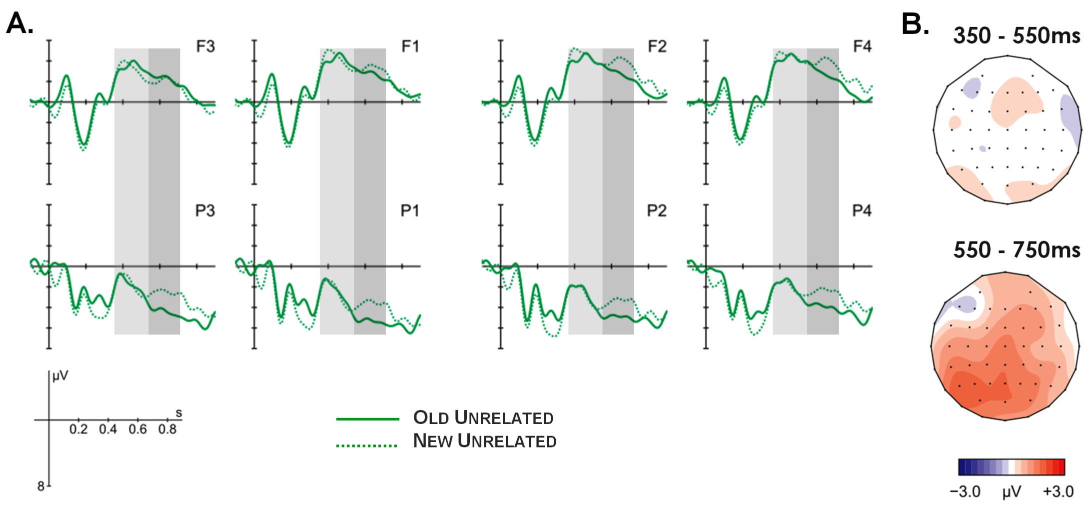


Figure 6.5: Experiment 1. Old/new effects elicited by correct old and new responses in the unrelated condition (data from 13 participants). Panel A shows ERP waveforms and panel B depicts corresponding topographic distribution of old minus new differences in the early (350-550ms) and late (550-750ms) time windows.

6.3.3.2 NEW ITEM ERP COMPARISONS

As described above, the early frontal old/new effects did not differ for the categorical and thematic conditions suggesting comparable engagement of familiarity in the associative recognition of the two relation types. However, it is possible that differential modulation of the ERP familiarity correlate was masked by simultaneously acting semantic memory processes indexed by the ERP semantic N400 component, a negative-going peak observed over centroparietal sites 300-500ms post-stimulus and showing attenuation of negativity with facilitated meaning processing (see Section 3.4.3, Kutas & Federmeier, 2000, 2011; Lau et al., 2008). Given prior evidence that categorical and thematic relations might show differences in semantic processing observed in conceptual priming effects (Koivisto & Revonsuo, 2001; Deacon et al., 2004; Sass et al., 2009), it is possible that the N400 was differentially modulated by the two types of relations in the current experiment, thus contaminating the early-frontal old/new effects. The possibility is especially interesting in light of theories linking the early frontal old/new effect to semantic processing rather than episodic recognition memory as such (Voss & Federmeier, 2011).

The following analyses aimed to investigate whether a) the early frontal old/new effects observed for categorical and thematic relations could have been differentially affected by conceptual processing effects and b) the early frontal old/new effects might be considered as functionally identical to semantic processing. For this purpose, I analyzed the ERP waveforms elicited by correctly rejected new categorical and thematic items, as well as unrelated fillers included as a baseline[2]. (see Figure 6.3.3.1 for the view from 8 electrode sites and Figure D.4 in Appendix D for an extended view). New items are arguably unconfounded by the relevant episodic memory effects, thus any differences in their waveforms can be taken to reflect semantic memory access effects. A four-way ANOVA with factors Relation (categorical, thematic, unrelated), Location (frontal, partietal), Hemisphere (left, right) and Site (inferior, superior) was conducted on grand average waveforms of the correctly rejected new items from the same time window as that chosen for the analysis of the early-frontal old-new effects, i.e. 350 – 550 ms post stimulus. The analysis revealed no effect of Relation and no interactions involving this factor, all p-values $> .15$.

Nonetheless, a closer visual inspection of the waveforms (Figure 6.3.3.1) suggested that semantic priming effects could have taken place in a smaller time window, about 350-470ms post-stimulus. In this time window all three relation-types evoked a negative-going peak, and this negativity was attenuated for the thematically related pairs on the parietal sites. I analysed the data from this time window to assure that semantic processing effects even from this restricted time window did not contaminate the early frontal old/new effects. To this end, a four-way ANOVA with factors Relation (categorical, thematic, unrelated), Location (frontal, parietal), Hemisphere (left, right) and Site (inferior, superior) was conducted on the data from 350-470ms. The analysis revealed a three-way interaction between Relation, Location and Site, $F(2, 30) = 3.262$, $p = .05$, but no effect of Relation and no other interactions including this factor, all p-values $> .15$. To resolve the interaction, paired samples t-tests were employed on the data from frontal and parietal locations, separately, collapsed across the factor Hemisphere. No modulation of the waveforms by Relation was observed at frontal superior and inferior ROIs, all p-values $> .61$, providing no evidence of differences between the ERPs evoked by three relation types over the frontal sites. This analysis makes it unlikely that the early-frontal old/new effects observed for thematic and categorical re-

[2]The data from all 16 participants (those included into the analysis of the categorical/thematic mnemonic effects) entered the analyses of correct rejections. The mean number of trials in the unrelated condition was 27.

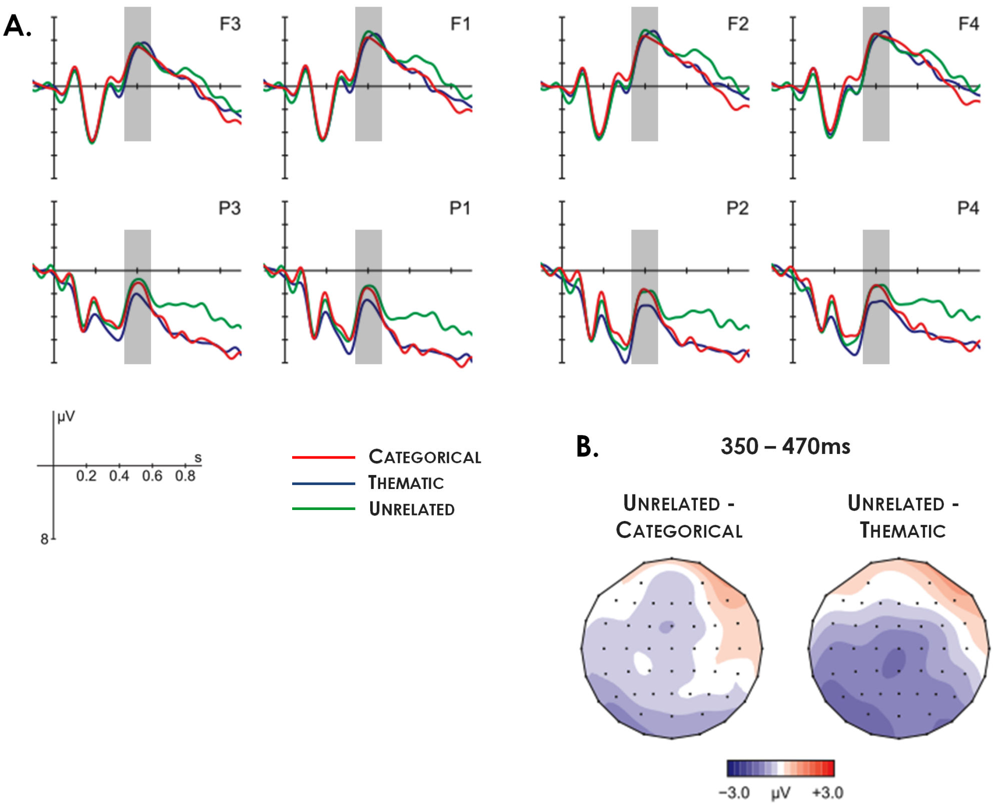


Figure 6.6: Experiment 1. ERPs elicited by correctly rejected new items in the categorical, thematic and unrelated conditions taken to reflect semantic N400. A) shows grand average ERPs and B) illustrates the scalp distribution of the unrelated minus categorical and unrelated minus thematic differences in the 350-470ms time window.

lations were differentially masked by semantic memory access effects. At parietal sites, at both inferior and superior ROIs, the results did not reveal any differences between categorical and unrelated pairs, both p-values $> .7$, but thematic-unrelated differences were significant at inferior and superior ROIs, $t(15) = 2.421$, $p = .03$ and $t(15) = 2.344$, $p = .03$ (one-tailed), respectively. In addition, ERPs tended to be more negative going in the categorical than in the thematic relation at superior parietal sites, $t(15) = 1.523$, $p = .08$ (one-tailed).

6.3.3.3 ANALYSES OF THE STUDY PHASE DATA

This sections deals with the analyses of behavioral and ERP data collected during the study phase. The analyses looked for any indications of differences in the encoding of categorical and thematic conditions due to mental imagery task. Because differences between the two conditions at encoding might in part explain differential pattern of engagement of associative recognition processes at test, the analyses were restricted to word pairs that were subsequently correctly endorsed as old. Of particular interest was the N400 component that is known to be sensitive to imagability of concepts (Nittono et al., 2002; West, 2000). The N400 elicited by the presentation of a second word from a pair, that is when the type of relation between the words was made explicit, was analyzed and compared between the categorical and thematic conditions.

Firstly, behavioral data from the study phase were analysed by comparing probabilities of imagery ratings for categorical and thematic conditions. The repeated measures ANOVA with factors Relation (categorical, thematic) and Rating Type (“image 1 clearer”, “image 2 clearer”, “both images equally clear”) yielded a significant Relation by Rating Type interaction, $F(2, 30) = 5.358$, $p = .01$. Subsequent paired contrasts revealed that the interaction reflected that participants were more likely to visualize both images equally clear in the categorical than in the thematic condition, $t(15) = 2.603$, $p = .04$, and were more likely to rate the first image as being more clear than the second in the thematic than in the categorical condition, $t(15) = 2.694$, $p = .05$.

Secondly, ERP analyses were conducted. The time window of 300 – 500ms after the onset of the second word was chosen for analysis in accordance with prior literature (Kutas & Federmeier, 2000, 2011). To capture the typical centro-parietal distribution of the N400, ERPs recorded from the central locations were included into the analyses in addition to those recorded from frontal and parietal locations (Figure 6.3.3.3 B, see also Figure figure:AppendStudyHitsExp1 in Appendix D). As the Figure 6.3.3.3 A shows, grand average ERP waveforms of the categorical and thematic conditions do not seem to considerably differ in the N400 time window[3].

To check whether the observed pattern is reliable, a series of analyses were conducted. The initial ANOVA included the factors Relation (categorical, thematic), Location (frontal, central, parietal), Hemisphere (left, right) and Site (inferior, superior). There was only a three-way interaction between factors Relation, Location and Hemisphere, $F(2, 30)=3.809$, $p = .034$, with all other effects including factor Relation failing to reach significance, p-values $> .206$. To resolve the interaction, separate contrasts were performed on the data from each of the 6 ROIs (right- and left-hemispheric ROIs at frontal, central and parietal locations with the data collapsed across factor Site at each ROI). Critically, none of the pairwise comparisons revealed any significant differences between the categorical and thematic conditions, all p-values $> .156$.

6.4 DISCUSSION

Experiment 1 explored whether long-standing categorical and thematic relationships between the paired concepts might differentially affect recognition memory for the associations. Manipulating the type of relational link between paired words in a standard associative recognition memory test enabled comparing the effects that these relations have on familiarity and recollection, as indexed by their putative electrophysiological signatures – early frontal and late parietal old/new effects, respectively. In accord with prior studies (Greve et al., 2007; Rhodes & Donaldson, 2008; Opitz & Cornell, 2006) both familiarity and recollection were expected to contribute to associative recognition of both relation types. The critical assumption underlying the comparison was that holistic

[3]Though visual observation suggests differences in the waveforms elicited in the categorical and thematic conditions ca. 600 – 750ms post-stimulus, the significance of this component is not clear. Therefore, ERP analyses were restricted only to the N400

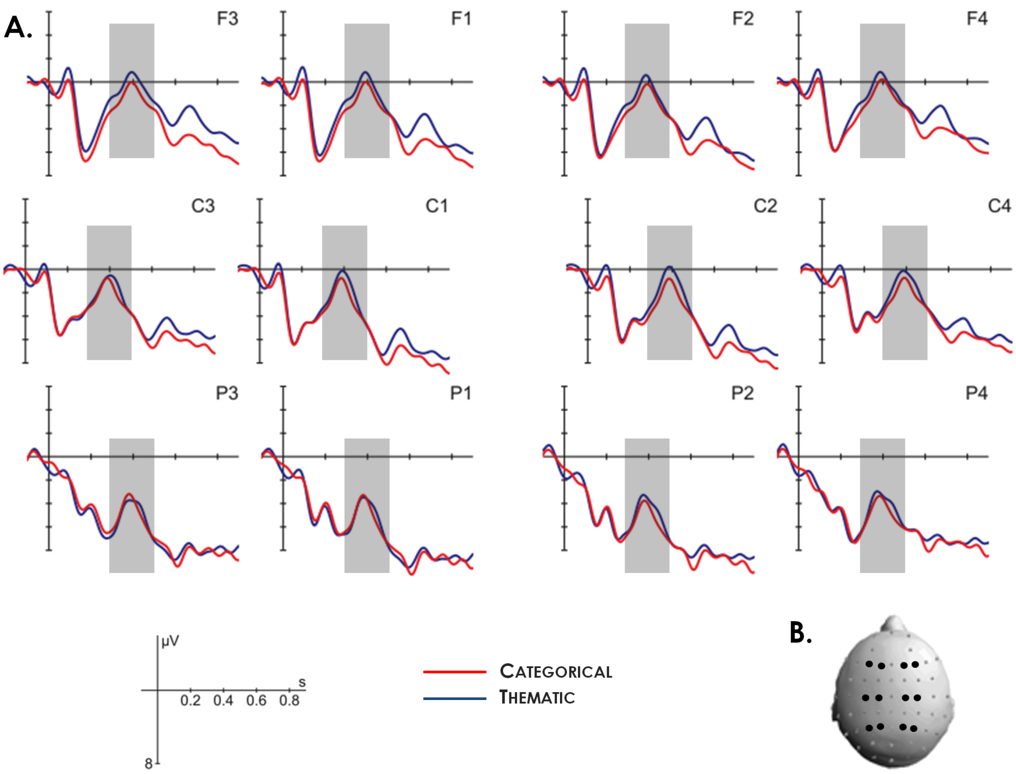


Figure 6.7: Experiment 1. (A) Study-phase ERPs elicited by the second word of those categorical and thematic word pairs which were subsequently correctly identified as old at test. The window of interest was 300-500ms (marked grey). (B) highlights the sites of electrodes (F3, F1, F2, F4; C3, C1, C2, C4 and P3, P1, P2, P4) included into analyses of the N400 effect as viewed from above.

nature of thematic associates, namely their integrability into a joint representation of a thematic scenario, might enhance contribution of familiarity and simultaneously reduce the involvement of recollection in associative recognition of relations of this type. The results revealed that associative recognition of both relation types was accompanied by comparably large early frontal old/new effects. In contrast, the two conditions differed with respect to a late parietal old/new effect that was present in the categorical condition only. Below I interpret functional significance of the observed ERP effects and discuss the factors that could have contributed to the observed modulation.

6.4.1 LATE PARIETAL OLD/NEW EFFECT AND BEHAVIORAL DIFFERENCES IN MEMORY PERFORMANCE IN THE CATEGORICAL AND THEMATIC CONDITIONS

Given comparable early frontal old/new effects in the categorical and thematic conditions, it appears that in the present experiment the type of relation primarily impacted the late-parietal old/new effect. The absence of this ERP correlate of recollection (Curran, 2000; Wilding, 2000; Friedman & Johnson, 2000) in the thematic condition implicates that its contribution was attenuated compared to the categorical condition. This result is consistent with the prediction that integrative nature of the thematic relation should allow for a reduction of the recollection-based recognition. However, given a robust relationship between better memory performance and a greater involvement of recollection in recognition tests (Rugg et al., 1998; Ullsperger et al., 2000), it merits exploring whether the observed pattern could be attributed to differences in mnemonic performance.

Though associative discriminability indexed by associative Pr was equal in the two conditions, behavioral results showed a higher Hit-rate and old-new Pr score in the categorical than in the thematic condition. Accordingly, it is possible that the presence of the late-parietal old/new effect in the categorical condition merely reflects that more items were correctly recognized in this condition compared to the thematic. To examine, whether quantitative difference in memory performance can explain the observed ERP pattern, a post-hoc analysis was conducted in which the six participants with the largest advantage in mnemonic performance on the categorical compared to thematic pairs were excluded (recognition accuracy for categorical pairs minus accuracy for thematic pairs, collapsed across old and new conditions, was bigger than .10). By doing so, I equalized the performance between the categorical and thematic pairings for both old and new items, both p-values $> .12$. Importantly, after equalizing the performance, the pattern of ERP results remained the same: a four-way ANOVA with the factors Relation, Type, Hemisphere and Site yielded a main effect of Type in the early time window for the frontal locations, $F\ (1,9) = 25.231$, $p < .01$, but no interaction between Type and Relation, $F\ (1,9) = .430$, $p = .\ 53$, suggesting comparable early frontal old/new effects in both conditions. Critically, at parietal locations in the late time window there was a signicant Type by Relation interaction, $F\ (1,\ 9) = 6.225$, $p = .03$, reflecting the presence of the late parietal old/new effect in the retrieval of the categorical relation only. Preservation of the ERP pattern even with equalized performance makes it unlikely that the late parietal old/new effect in the categorical condition can be entirely attributed to a higher recognition accuracy in this condition.

6.4.2 LATE PARIETAL OLD/NEW EFFECT AND THE EFFECT OF IMAGERY TASK AT ENCODING

An alternative account is that the late-parietal old/new effect might reflect that for the correctly recognized categorical pairs, more details of the study phase were available at retrieval as a consequence of more profound encoding in this condition. This explanation relates to the levels of processing account (Craik & Lockhart, 1972, see Chapter 2.3.2) predicting that more elaborative encoding at study stimulates a formation of stronger memory traces. This, in turn, increases participant's capacity to recollect some details about the study episode, as reflected in the late-parietal old/new effect in ERP studies (Rugg et al., 1998; Nyhus & Curran, 2009) and the gradation of this effect according to the amount of the retrieved information (Vilberg et al., 2006). In the context of the present experiment it is conceivable that such an encoding task as mental imagery could have promoted a more elaborative and efficient encoding of the categorical relations but less so of the thematic relations. As was described in Section 3.4.1, grouping concepts under one category typically occurs on the basis of a considerable amount of feature overlap between these concepts (Estes et al., 2011; Hampton, 2000; Markman & Wisniewski, 1997). Confirming this are the results of the pre-experimental rating of materials suggesting that participants perceived categorically related concepts as sharing more semantic features than thematically related ones (see also rating studies by Estes & Jones, 2009; Perraudin & Mounoud, 2009; Wisniewski & Bassok, 1999). Feature similarity often refers to perceptual similarity with some types of concepts, particularly natural things and non-manipulable artifacts, *fox – wolf, carpet – curtain*, characterized by a higher degree of perceptual similarity, while others - by a smaller degree, e.g. manipulable objects such as *hammer – saw* (Cree & McRae, 2003; McRae, Cree, Seidenberg, & McNorgan, 2005). Confirming that perceptual similarity is of a crucial importance for categorical relatedness, recent neuropsychological research comparing processing of categorical and thematic relations demonstrated that processing categorically related concepts heavily loads on visual/perceptual processing and actively involves bilateral visual cortical areas (Kalenine et al., 2009) and precuneus (Kotz et al., 2002; Sachs et al., 2008). Regarding the present experiment, it is therefore possible that in the context of a mental imagery task categorically related concepts engaged mental visualization mechanisms more actively, and were processed in a more elaborative way during the study phase, leading to the encoding of more detailed information for the word pairs of this type.

In search of an indication that mental imagery might have promoted deeper encoding of the categorically related concepts and a subsequent enhanced recollection in this condition as compared to the thematic condition, behavioral and electrophysiological data from the study phase were analyzed. As the ultimate purpose of the analyses was to investigate whether differences between categorical and thematic conditions at the study phase might be related to subsequent recognition memory differences observed at test phase, analyses were conducted on a set of items common to both phases – that is word pairs subsequently correctly recognized as old (for a similar approach see a pioneering work by Sanquist, Rohrbaugh, Syndulko, and Lindsley (1980) related to subsequent memory effects).

First, behavioral estimates of efficiency of the mental imagery task were compared. The results suggested that in the categorical condition participants were more likely to visualize both images equally clear than in the thematic condition. In the context of a mental imagery task with a requirement to sequentially imagine concept one, it is possible that once a vivid mental image was already formed for concept 1, forming a mental image for concept 2 was rather easy in case of categorical relatedness, as a significant amount of perceptual features common to both concepts was already in the active state. Thus, participants could have rapidly built a global image and further engaged in imagining details specific to concept 2. This, in contrast, might not have been the case for thematically related pairs. As concepts in this condition do not have many common features, it is therefore possible in order to imagine concept 2 participants first had to inhibit the active features of concept 1 and then imagine a concept 2 from anew.

To find further evidence for the differential effect of mental imagery on the encoding, ERPs of the items later correctly endorsed as old were compared. Of specific interest was the the N400 elicited by the presentation of a second word from a pair, that is when the type of relation between the words was made explicit. Along with being associated with meaning processing, the N400 was recently shown to be sensitive to imagery value of the concepts (Nittono et al., 2002; West, 2000): words characterized by a higher imagability produce a larger N400 than those having a lower imagability value, possibly due to recruiting a broader network (both verbal and visual representational systems (Paivio, 1991) in processing. As in the present experiment behavioral results indicate that both concepts were vividly visualized in the categorical condition, a more negative N400 in the categorical condition might be expected than in the thematic condition. The outcome of the analyses revealed the N400 did not statistically differ between the categorical and thematic conditions. In the absence of the electrophysiological marker of the encoding differences between the two conditions is it is therefore somewhat precarious to claim that the differential ERP pattern observed at retrieval might be largely explained by task-related differences emerging during the encoding.

6.4.3 MODULATION OF THE LATE PARIETAL OLD/NEW EFFECT BY CATEGORICAL AND THEMATIC RELATEDNESS

The possibility remains however that the differential modulation of the late-parietal old/new effect might be caused by differences in the nature of the categorical and thematic semantic relations.

As described in Section 3.1, recollection is thought to be a primary process in recognition of associations (D. I. Donaldson & Rugg, 1998; Hockley & Consoli, 1999; Yonelinas, 1997; Giovanello et al., 2006), which requires identifying a previous occurrence of several elements and recognizing a relational link between them. The pattern of results for the categorically-related pairs clearly demonstrates the presence of a reliable late parietal old/new effect. Importantly, this effect is topographically dissociable from the early frontal old/new effect implying contribution from different underlying neural processes at the two temporal stages – familiarity and recollection – to associative recognition of this relation type. The distribution of the late effect was also distinct from that of the early parietal old/new effect, with the latter possibly being a mixture of the episodic and semantic effects. This inference follows from an observation that apart from old/new differences in the early time window on parietal sites, semantic priming effects on the parietal electrodes were observed in the overlapping time window (350 – 470 ms post suggested). Overall, these results are in line with other ERP findings reported by Greve et al. (2007); Rhodes and Donaldson (2008), who likewise observed that both familiarity and recollection are engaged in associative recognition of categorically related pairs.

The novel aspect of the present results is the absence of the electrophysiological marker of recollection in the thematic condition. Section 3.2 already noted that the extent to which recollection is engaged in associative recognition seems to be reduced when items can be unitized into a single representation (Quamme et al., 2007; Bader et al., 2010; Jäger et al., 2006; Ford et al., 2010). Experimentally and pre-experimentally established compounds are frequently referred to as an example of unitized representations and their use in associative recognition tests largely confirmed a differential involvement of familiarity and recollection in their recognition (Quamme et al., 2007; Giovanello et al., 2006; Bader et al., 2010; Ford et al., 2010). In the present investigation, we constructed materials such that to avoid using established compounds. Nevertheless, pre-experimental-ratings revealed that thematically related words have a bigger capacity to form a plausible compound compared to categorically related words, opening a possibility that something akin to a spontaneous compound-formation occurred when participants encoded some of the thematic pairings. Though such a process could have indeed taken place, it appears unlikely that spontaneous compound formation can entirely account for the results given that we employed a task in which each word had to be considered separately in the single item imagery task thus preventing treating the two words as one compound.

It can be something else in the nature of the thematic relations employed in the present experiment that makes them akin to unitized representations, such as capacity to be integrated into a thematic scenario and a relatively high associative strength – both characteristics attributed to thematic pairs according to the pre-experimental ratings (Section 5.4). Speaking to the first issue, thematically related concepts can be thought of as constituents of a joint scenario which complement each other in the roles that they perform in the theme (Estes et al., 2011; Lin & Murphy, 2001; Murphy, 2001). Estes and Jones (2009) demonstrated that whenever two concepts which fit a common theme are encountered, they rapidly get integrated as evidenced by facilitated processing of a target word in a priming paradigm (for a similar finding see Badham et al., in press). The degree of thematic integrability can be further strengthened by a presence of a strong associative connection between the concepts which emerges with their repeated co-occurrence, such as in *hen – egg*. Opitz and Cornell (2006) advanced the idea that such strongly associated items form holistic and easy-to-access representations. In the present experiment, I employed conventional, i.e. well-established and salient, thematic relations which arise as a result of a repeated co-occurrence of items in the prototypical situational contexts and are therefore strongly associated (confirmed by the pre-experimental ratings; see also Lin and Murphy (2001); Estes et al. (2011)). Hence, it seems plausible that thematically related words in the present study, e.g., *actor – stage*, could have been processed as holistic representations, such as in terms of associated contextual frames (e.g., theater), thereby reducing contribution of recollection to associative recognition of this relation type.

6.4.4 EARLY FRONTAL OLD/NEW EFFECTS: DISSOCIATING EPISODIC FAMILIARITY AND SEMANTIC PROCESSING EFFECTS

Robust old/new effects were observed in the early time window when to-be-remembered words were categorically and thematically related. In line with previous research, these effects can be viewed as markers of familiarity-based recognition. As no early-frontal old-new effects were found in the post-hoc analysis of the unrelated condition, these results confirm an idea advanced by Greve et al. (2007) that semantic relatedness might function as a kind of organizing link that puts the concepts into familiarity-supporting representations. Moreover, the present findings extend this thesis to such type of semantic relatedness, as thematic relatedness, and strongly suggest that organizing items around themes not only supports familiarity-based item recognition (Opitz & Cornell, 2006) but also associative recognition.

There is, however, some discrepancy in literature whether the early frontal old/new effects might reflect pure ERP signatures of episodic memory (Stenberg, Hellman, Johansson, & Rosën, 2009; Bridger et al., in preparation) and/or might be related to conceptual priming (Voss & Paller, 2007; Paller, Voss, & Boehm, 2007; Voss & Federmeier, 2011). Conceptual priming is an implicit memory phenomenon referring to a more fluent processing of meaningful information, such as when accessing one concept pre-activates a representation of the related concept thereby facilitating its processing upon the actual encounter (Neely, 1991; Masson, 1995). In the electrophysiological research, conceptual priming effects are typically indexed by an attenuation of the negative-going peak observed 300-500ms post – stimulus after words that are congruent with the preceding context/word compared to incongruent ones (C. Brown & Hagoort, 1993; Bentin S. & Hillyard, 1995; Kutas & Federmeier, 2000, 2011). This so-called semantic N400 effect, though typically having a centro-parietal maximum (Wolk et al., 2004; Rhodes & Donaldson, 2007a; Kutas & Federmeier, 2011), might sometimes show a more frontal distribution (Ganis, Kutas, & Sereno, 1996; Holcomb & McPherson, 1994) thus becoming difficult to distinguish from the familiarity-related early-frontal old/new effect (Voss & Federmeier, 2011).

Importantly, facilitated conceptual processing might interfere with episodic recognition processes in recognition experiments in that participants simply attribute easier processing of an item to its previous encounter and eventually endorse an item as old (Whittlesea & Williams, 2001; Wolk et al., 2004). Therefore, it was worth exploring whether conceptual priming effects could have been different for the two relation types in the present experiment and, if so, whether the episodic early-frontal old/new effects could have been masked by conceptual priming effects. Therefore, I compared correctly rejected new word pairs to all three relation types (categorical, thematic and unrelated) under the assumption that ERPs evoked by items with no prior study history should be unconfounded by the relevant episodic memory effects, thus reflecting conceptual priming effects. Semantic relationship did not modulate the ERP waveforms in the time window from 350 to 550ms – that is in the interval, selected for the analysis of the early frontal old/new effects. However, when restricting the time window to 350-470ms in accord with the visual inspection of the N400 peak, a modulation by relation was observed at parietal locations, with the largest attenuation in the thematic condition compared to unrelated and categorical.

These results are informative in several ways. Firstly, in addition to the debate about the functional significance of the early frontal old/new effect, the results demonstrate that the early frontal ERPs were not differentially modulated by a relation suggesting that the effects on the frontal locations in the early time window are unlikely to reflect conceptual priming. Secondly, the absence of any modulation by the semantic relatedness at frontal sites in the early time window makes it improbable that the early frontal old/new effects might have been differentially masked by simultaneously acting differential conceptual priming effects for the categorical and thematic relations. Thirdly, parietally distributed modulation of the N400 by a relation type indicates that this effect should be considered as functionally and electrophysiologically distinct from the early frontal old/new effect.

The results of these analyses speak to the interpretation of equally large contribution of familiarity to recognition of thematic and categorical relations in the present experiment. Though no predicted enhancement of the early frontal old/new effect was observed, the absence of the electrophysiological correlate of recollection in this condition suggests that familiarity on its own might have been sufficient to support associative recognition in this condition.

6.5 CONCLUDING REMARKS

Taken together, the results of Experiment 1 further extend the evidence that semantic memory interacts with episodic memory (Opitz & Cornell, 2006; Greve et al., 2007) in that associative recognition differentially engages mnemonic mechanisms depending on the type of pre-existing semantic relation in a word pair. In line with previous findings (Rhodes & Donaldson, 2008; Greve et al., 2007; M. M. Patterson et al., 2009) both familiarity and recollection seem to play a role in associative recognition of categorically related concepts. In contrast, contribution of recollection is attenuated when the paired concepts can be integrated into bound thematic representations, tentatively suggesting that familiarity on its own might provide an efficient mechanism for associative recognition of this relation type.

CHAPTER 7

EXPERIMENT 2

7.1 INTRODUCTION

To recapitulate, results of Experiment 1 showed that both familiarity and recollection might be engaged in associative recognition of the categorically related pairs. In contrast, contribution of recollection seems to be attenuated in the recognition of the thematically related pairs – a finding that hints for a critical role of familiarity in the associative recognition of the thematically-related pairs. In light of no pronounced differences in the ERP signature of familiarity in Experiment 1 it might be, however, premature to claim that familiarity is engaged in associative recognition of the thematic relation more than of the categorical relation.

Experiment 2 was designed to directly address this possibility by creating such testing conditions that would allow the potential differences in familiarity to show up. This was achieved by employing a testing paradigm that provides more opportunity for a successful performance of the associative recognition task on the basis of familiarity. The test format of Experiment 2 was changed from a triple old/rearranged/new discrimination used in Experiment 1 to a two-alternative forced–choice (FC) format (for studies using a similar approach to probing associative recognition see Bunge, Burrows, & Wagner, 2004; Bastin & Linden, 2005; Jäger et al., 2006; M. M. Patterson & Hertzog, 2010). In FC associative recognition tests, participants are presented with one "main" word (e.g., word A) and two alternatives (B and C) out of which one was paired with the main word during the study and another one appeared in a different pair. A participant then has to decide which of the two pairs (A–B or A–C) was actually learned during the study phase (for an illustration of the test trial procedure see Figure 7.1. A standard Y/N recognition task is thought to endorse a recall-to-reject strategy during retrieval (Clark, Hori, & Callan, 1993; M. M. Patterson & Hertzog, 2010) in that participants have to recollect the information about the actual occurrence of a word pair in order to differentiate between old and rearranged pairs. In contrast, a forced-choice task is solvable both by recollecting the details of a study episode but also by simply assessing associative familiarity of each of the pairs (Clark et al., 1993; Norman & O'Reilly, 2003; M. M. Patterson & Hertzog, 2010). In the latter case, participants simply evaluate familiarity strength of the pairs relative to each other and choose the one with the strongest familiarity signal. Employing a testing paradigm that provides more flexibility for contribution of both recollection and familiarity to associative recognition was hypothesized to promote familiarity-based recognition especially for the type of stimuli that are genuinely more suitable for familiarity-based retrieval, i.e. thematically-related word pairs.

Another major modification introduced to the experimental procedure concerned the mnemonic measures employed and directly followed from the change of the experimental paradigm. As test trial structure of a forced-choice associative recognition task typically presupposes a simultaneous presentation of three stimuli (main word and two alternative paired associates), functional significance of the ERPs locked to the onset of the stimulus display is dubious: apart from actually mirroring mnemonic processes, ERPs can also reflect, for instance, stimulus selection and decision-making processes. Therefore, Experiment 2 estimated familiarity and recollection with a behavioral Remember-Know procedure (Tulving, 1985, see Section1.3.1 for a detailed description of the procedure). Operational definitions of familiarity and recollection used in the Remember-Know (RK) procedure are different from those used in the ERP research as they reflect subjective evaluation of the engaged mnemonic processes (Yonelinas, 2002). Nonetheless, both measures provide commonly accepted estimates of familiarity and recollection (see Sections 1.3.1 and 1.3.2 for a review of research providing evidence for correspondence of measures provided by RK and other methods, including ERPs). In the RK procedure, participants have to monitor retrieval processing and for each item identified as "old" or "recombined" indicate whether recognition was based on familiarity ("know"-response) or recollection ("remember"-response"). Though the original RK procedure (Tulving, 1985) uses only two types of responses, I additionally incorporated a "guess" (G) response category to prevent pure guessing-based answers from being included into the "know"-response category (Gardiner et al., 1998; Eldridge et al., 2002) and to highlight qualitative differences between the processes. Following recommendations of Eldridge et al. (2002), a two-step response procedure (first, recognition decision and then RKG judgment) was employed in order to prevent participants' treatment of different types of responses as a measure of response confidence (see Section 1.3.1).

To summarize, Experiment 2 was conducted to investigate potential differences in familiarity-based associative recognition of the categorical and thematic pairs in such a testing paradigm that can arguably promote engagement of familiarity. Familiarity was predicted to make a stronger contribution to associative recognition of the thematically than categorically related pairs.

7.2 METHOD

7.2.1 PARTICIPANTS

Twenty-four participants took part in Experiment 2 for payment or course credit. The data from four participants were discarded due to their near chance performance (less than 52% correct, 1.5 *SD* below the mean proportion of correct responses). For the remaining 20 participants (11 female, mean age 21 y.o., age range from 19 to 24 years) recognition accuracy was above 61%.

7.2.2 MATERIALS

Experiment 2 used the same set of materials as Experiment 1 (see Appendix B). During the study phase, participants learned 30 categorical, 30 thematic, and 120 unrelated (30 targets and 90 fillers as explained below) word pairs. At test, 90 triples were presented on which a forced-choice recognition task had to be performed. Each triplet included an intact pair that came a set of from previously studied 30 categorical, 30 thematic and 30 unrelated pairs. The third word in each test triplet was taken from an unrelated filler word pair likewise learned during the study phase (see Table 7.2.2).

In terms of stimulus sets, the following principle was used to construct materials for Experiment 2: for each participant, 30 sets were assigned to a related condition and 15 – to an unrelated condition. From the sets assigned to the related condition 30 categorical and 30 thematic pairs, as well as 60 unrelated fillers were produced (see Table 7.2.2, example for Set 1). From the sets assigned to the unrelated condition, 30 unrelated pairs reappeared as intact target pairs at test and 30 served as unrelated fillers (see Table 7.2.2, example for Set 2). The assignment of items to relation- and test-conditions was counterbalanced across participants.

SET	CONDITION	QUADRUPLET	STUDY				TEST
1	RELATED	1	*CATEGORICAL OLD*	DANCER	SINGER	*TEST TRIPLET*	DANCER ACTOR
			UNRELATED FILLER	ACTOR	STRAWBERRY		SINGER
		2	*THEMATIC OLD*	CHERRY	ORCHARD	*TEST TRIPLET*	PLUM CHERRY
			UNRELATED FILLER	PLUM	STAGE		ORCHARD
2	UNRELATED	1	*UNRELATED OLD*	RING	MEADOW	*TEST TRIPLET*	RING BRACELET
			UNRELATED FILLER	BRACELET	SUN		MEADOW
		2	*UNRELATED OLD*	DESERT	NECKLACE	*TEST TRIPLET*	PRAIRIE DESERT
			UNRELATED FILLER	PRAIRIE	PRESENT		NECKLACE

Table 7.1: Experiment 2. Illustration of item construction.

7.2.3 DESIGN AND PROCEDURE

E-prime software was used to implement Experiment 2 and RB Series Cedrus response box served as an input device. Stimuli were presented on a 19" monitor (Courier New, font size 22) in black on a white background.

Experiment 2 consisted of five study-test blocks. Dividing the experiment into separate study-test blocks was motivated by two considerations. Firstly, given a large total number of the to-be-learned word pairs (*n*=180), this allowed to achieve above-chance levels of recognition performance as revealed by a series of piloting experiments. Second, familiarity-based recognition was assumed to be better captured with short study-test retention intervals. Longer study-test retention intervals, as in case of a large lag and a large number of interveaning items between the occurences of an item at study and at test, are known to considerably diminish familiarity-based recognition (for a review see Yonelinas, 2002; Yonelinas & Levy, 2002). During each study phase, 36 word pairs (6 categorical, 6 thematic, and 24 unrelated) were learned. At test, test 18 triplets (6 categorical, 6 thematic and 6 unrelated) were presented for a forced-choice recognition task. 1-minute simple arithmetics task separated each study-test sequence.

During the study phase, a trial began with a 1000ms fixation cross, followed by a 250ms blank screen (Figure 7.1). After that two words (categorically/thematically related or unrelated) were presented on the screen for 2000ms with a square box below each word. Participants' task was to imagine an object named by each word in the corresponding box. After that, a question mark appeared on the screen for 2000ms prompting participants to compare the imagined objects. As in Experiment 1, participants had three response options: "image 1 was clearer", "image 2 was clearer", and "both images wer equally clear". In Experiment 2, words were presented simultaneously to maximize overlap between the study and test phase presentation styles and to elimilate temporal information about the sequence of item presentation – a potentially recollection-triggering mnemonic aspect (Yonelinas, 2002).

Each test phase trial (Figure 7.1) began with a fixation cross for 1000ms. Then a blank screen was presented for 250ms, after which 3 words appeared on the screen for 2500ms. The words were presented in a triangular fashion: one word was presented in the center of the display, and two other words were positioned on one line above it, one to the left and to the right of the center. Participants had to judge which of the two upper words was paired with a bottom-most word (that is, they had to discriminate between old and rearranged pairs) and indicate that with a point/middle finger of their left hand. After that, participants had 1800ms time to decide whether they made their response based on remembering, knowing or just guessing and indicate their decision by pressing one of the correspondingly marked buttons with point/middle/ring finger of their right hand. The instructions for remember and know responses types, adopted from Gardiner and Richardson-Klavehn (2000), can be found in Appendix C. Response assignment to the buttons of the response box and hand was counterbalanced across participants.

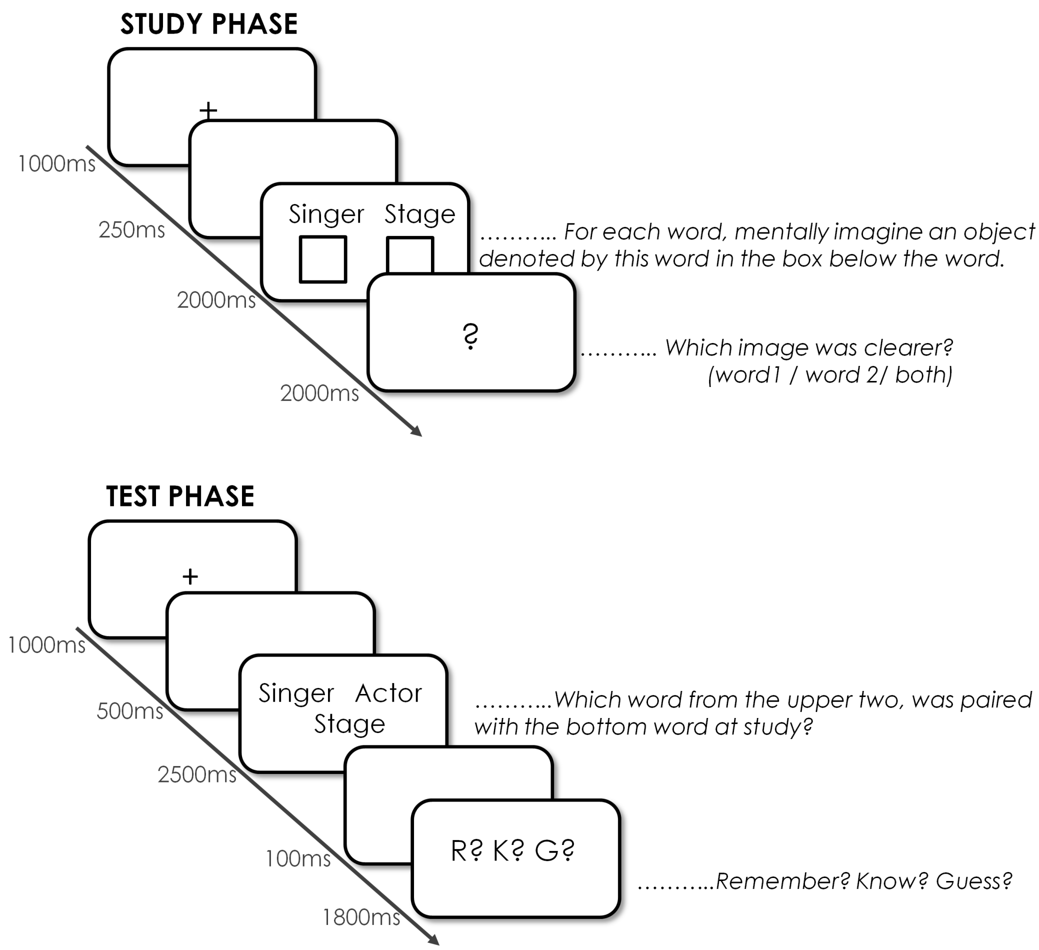


Figure 7.1: Experiment 2. Illustration of the experimental procedure: the upper pannel shows a trial procedure during the study phase; the lower pannel represent trial procedure during the test phase.

7.3 RESULTS

Unrelated pairs were included at test to divert participants' attention from the main relations manipulated, and were not analyzed. All the reported hit rates and error rates were computed as suggested by Snodgrass and Corwin (1988) (see Section 6.2.5). Hit-rates were computed separately for the categorical and thematic conditions, and, as Table 7.3 shows, they did not significantly differ, $t(19) = .34$, $p = .74$.

Further, separately for each condition, recollection-based hit rate was computed as a probability of a participant giving a correct response followed by "R"-judgment (Table 7.3). Similarly, separately for categorical and thematic conditions, I computed K-based recognition rates ($M = .10$ (.02) and $M = .12$ (.01), respectively) and G-based hit rates ($M = .04$ (.01) and $M = .03$ (.05), respectively). K-based hit-rates were then corrected in accord with independence assumption (Yonelinas & Jacoby, 1995). As reviewed in Section 1.3.1, RK procedure allows participant to endorse each item either as recollected or familiar, thus leading to the fact that those trials on which familiarity

	Hits	Hits			Errors		
		R	K	G	R	K	G
Categorical	.79 (.02)	.68 (.03)	.29 (.04)	.14 (.03)	.06 (.03)	.09 (.07)	.06 (.05)
Thematic	.78 (.02)	.66 (.02)	.36 (.04)	.11 (.02)	.08 (.06)	.08 (.06)	.05 (.03)

Table 7.2: Experiment 2. Mean hit rates, as well as R, K and G rates for correct and error responses (standard error) separated for categorical and thematic conditions.

was operating along with recollection are not included into the estimates of familiarity. To avoid such an underestimation, familiarity should therefore be computed as probability that an item received a Know response, given it was not recollected. i.e., K = Hit K / (1 – Hit R) (Yonelinas, 2002). Similarly, guess-based hit rates may be computed as probability of correct guess responses divided by opportunity to respond "guess", i.e., when an item is neither recollected, nor familiar: G = Hit G / (1 – Hit R) (1– Hit K) (for a similar logic, see Erdfelder, Cüpper, Auer, & Undorf, 2007). All further computations were conducted on corrected K- and G-based hit rates (see Table 7.3). Planned contrasts revealed that there were no significant differences in R- and G-based hit rates between the categorical and thematic conditions, $t(19) = .533$, $p = .6$ and $t(19) = 1.462$, $p = .16$, respectively. However, in accordance with the predictions, differences in K-estimates were observed, $t(19) = 2.246$, $p = .037$. Similarly to hits, contribution of different memory states was computed for error responses. Pairwise comparisons did not reveal any significant difference neither in recollection, nor in familiarity or guessing for erroneous responses, all *p*-values $> .24$.

Reaction time data (Table 7.3) associated with correct responses were also analysed. Comparing reaction times of correct responses did not yield any significant difference between the categorical and thematic conditions, $t(19) = .002$, $p = .99$. Further, for each participant RTs were split according to the type of subsequent mnemonic judgment. A two-way ANOVA with factors Relation (categorical, thematic) and Memory State (remember, know) was conducted RTs associated with R and K-responses. G-responses were discarded from this analysis as many participants (n=18) did not indicate that they relied on guessting in one or neither condition. The results of the analysis revealed only a main effect of Memory State, $F(1, 16) = 62.668$, $p < .001$, indicating that it took longer to provide a K- than an R-response.

7.3.1 POST-HOC ANALYSES

The results of the above analyses revealed differences in the correct K-based responding between the categorical and thematic conditions, whereas no differences were observed in the R-based

	Hits	Hits		
		R	K	G
Categorical	1864 (26)	1821 (31)	2118 (70)	2191(117)
Thematic	1865 (30)	1795(31)	2220 (55)	2385 (129)

Table 7.3: Experiment 2. Mean reaction times associated with correct responses (standard error) for categorical and thematic conditions. Provided are also RTs separated according to the subsequently given type of memory judgment.

hit-rates. To gain further insights into recognition processes with regard to the relation type, I splitted participants into two groups on the basis of the differences in accuracy of responding in the categorical and thematic conditions. That is, participants with a numerically larger hit-rate in the categorical than thematic condition were assigned to "categorical preference" group, while those demonstrating the opposite pattern were assigned to the "thematic preference" group. Two participants who performed equally well in both conditions, were randomly ordered to one of the groups. Splitting the data in this way resulted in creating two participant groups: those with a significantly higher Hit-rate in the categorical than thematic condition, $t(9) = 4.725$, $p = .001$, and those with a higher hit-rate in the thematic compared to the categorical condition, $t(9) = 3.286$, $p = .009$. The rationale behind dividing the participants into two groups was to explore which recognition process was driving successful recognition of the preferred relation as compared to the dispreferred one. Therefore, separately within each group, R-, K-, and G- based hit rates (see Table 7.3.1) were then compared between categorical and thematic conditions. The outcome of these contrasts yielded higher R-based responding in the categorical than in the thematic condtion within the "categorical preference" group, $t(9) = 4.543$, $p = .001$. Contrary to that, a higher K-based responding in the thematic than in the categorical condition was found in the "thematic preference" group, $t(9) = 4.846$, $p = .001$. No further contrasts turned out significant, all $p > .153$.

These split-group analyses suggested that successful recognition of the categorical pairs requires recollection while recognition of the thematic pairs actively engages familiarity. Keeping this in mind, I hypothesized that there should be a positive linear relationship between participants' overall reliance on recollection as a retrieval process and the accuracy of recognition of the categorical pairs. Conversely, I predicted a similar relationship between the overall reliance on familiarity throughout the experiment and the recognition accuracy of the thematic pairs. To test these predictions, I correlated the probability of a correct response to the categorical pairs and to the thematic pairs with estimates of participant's overall reliance on recollection and familiarity, computed as R- and K-hit rates, respectively, collapsed across Relation. Collapsing R- and K-rates across Relation was justified by post-experimental debriefing that revealed that participants were unaware of the main experimental manipulation, noticing only the related unrelated distinction. The results

	Categorically related pairs				Thematically related pairs			
	Hit-rate	R	K	G	Hit-rate	R	K	G
Group with a categorical preference	.82 (.02)	.75 (.02)	.28 (.05)	.14 (.04)	.73 (.02)	.64 (.03)	.27 (.04)	.08 (.02)
Group with a thematic preference	.75 (.03)	.60(.05)	.29 (.06)	.15 (.05)	.83 (.02)	.67 (.03)	.46 (.05)	.13 (.03)

Table 7.4: Experiment 2. Mean hit and R-rates, corrected K and G hit-rates for categorically and thematically related pairs. The values are presented separately for a participant group with a higher recognition performance in the categorical condition as compared to the thematic ("categorical preference") and a participant group with a higher performance in the thematic condition ("thematic preference")

of correlational analyses show a positive linear relationship between reliance on recollection and recognition accuracy in the categorical condition, $r = .79$, $n = 20$, $p < .01$ (Figure 7.3.1A). No such correlation was observed for the thematic pairs, $r = .14$, $n = 20$, $p > .05$ (Figure 7.3.1C). Conversely, estimate of overall reliance on familiarity correlated with accurate responding in the thematic condition, $r = .65$, $n = 20$, $p < .01$ (Figure 7.3.1D). No significant correlation was found between familiarity-based recognition and recognition accuracy in the categorical condition, $r = .07$, $n = 20$, $p > .05$ (Figure 7.3.1B).

7.4 DISCUSSION

Experiment 2 aimed to assess potential differences in the engagement of familiarity in associative recognition of the categorically and thematically related word pairs in such a testing paradigm that allows for a flexible involvement of recollection and familiarity in solving the task. Participants first studied paired words that were either categorically/thematically related or unrelated to each other (distracter condition) and subsequently performed a forced-choice associative recognition test in which they had to discriminate between old and rearranged pairs. Upon providing a recognition response, participants indicated whether they responded on the basis of recollection (R), familiarity (K) or by pure guessing (G).

Overall, participants tended to rely on recollection more than familiarity in both conditions. Comparing categorical and thematic conditions revealed that participants provided more K-responses following correctly recognized thematically than categorically related word pairs, whereas, R-based and G-based hit rates did not significantly differ between the conditions. In accord with the predictions, this implies that familiarity was engaged in associative recognition of the thematic condition to a greater extent than in the categorical condition. It is important to note that differences in the engagement of familiarity between the two conditions may not be attributed to

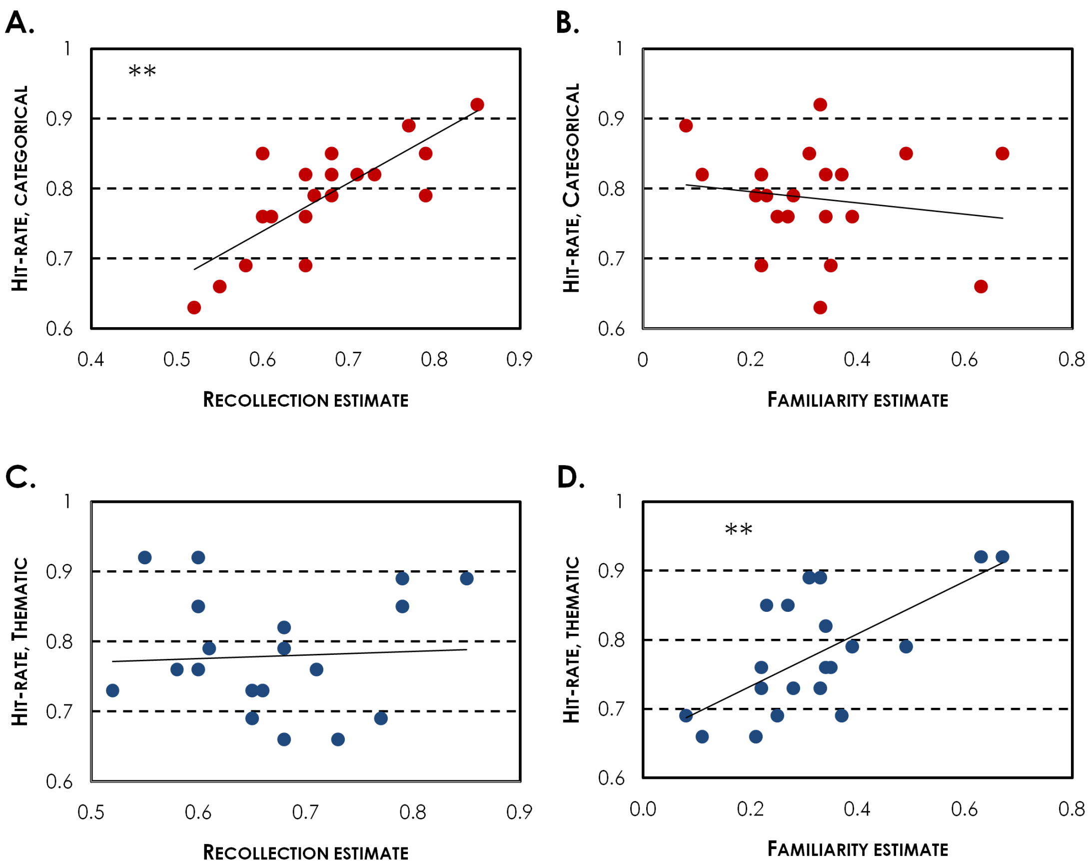


Figure 7.2: Experiment 2. Correlations between general reliance of recollection (R) and familiarity (F) with Hit-Rates in the categorical (A and B, respectively) and thematic conditions, (C and D).

quantitative differences in the recognition performance because of similar overall response accuracy (Hit-rates) in the two conditions.

Below I discuss several points concerning the results of Experiment 2. First, the effect of employing a forced-choice format on the outcome of the experiment is explained from the perspective of previous research. Second, indications of asymmetries in familiarity and recollection-based recognition of categorical and thematic relations are examined. Third, arguments against interpreting the data from the perspective of single-process models are reviewed. Finally, I outline the aspects of experimental procedure employed in Experiment 2 that could potentially account for high-levels of recollection-based remembering in both conditions.

7.4.1 EFFECTS OF THE FC FORMAT

Though several structural changes were introduced to Experiment 2 as compared to Experiment 1 (discussed further), the change of the test format appears to be one of the critical aspects of the new procedure. Experiment 1 employed a standard triple-choice old/rearranged/new format (analogous to a Yes/No item recognition paradigm), whereas Experiment 2 used a forced-choice (FC) format. These test formats seem to set differential requirements on the engagement of recollection and familiarity in cases when studied items and related lures are highly similar. Primary evidence for that comes from research on item recognition. Patient YR with selective hippocampal damage, thought to primarily affect recollection while sparing familiarity, was profoundly impaired on Y/N recognition tests, while performing comparably to controls on FC tests when studied and lure items were conceptually/perceptually similar (Holdstock et al., 2002; Mayes & Montaldi, 2001; Mayes et al., 2002). This suggests that when targets and lures are related, successfully performing a Y/N task necessarily requires hippocampally-driven recollection, whereas a forced-choice format allows to mitigate the critical role of recollection and to solve to task on the basis of familiarity. This pattern was replicated with patients with a mild-cognitive impairment associated with hippocampal and entorhinal atrophy (Westerberg et al., 2006) and with healthy participants by means of a modified remember-know paradigm (Migo et al., 2009).

Why recollection seems to be of crucial importance to Y/N but not to FC tests when studied and lure items are similar can be accounted for by Complementary Learning Systems framework (O'Reilly & Norman, 2002; Norman & O'Reilly, 2003; Norman, 2010). As described in Section 1.2.2, MTL regions outside of hippocampus (primarily, perirhinal cortex) linked to familiarity-based recognition tend to assign rather broad, non-specific representations to the incoming information during learning. During Y/N recognition tests, representations activated by studied items and related lures strongly overlap producing high familiarity signal in both cases. Consequently, the distributions of studied and unstudied related items on the familiarity strength axis overlap to such an extent that it is impossible to set a response criterion that would reliably differentiate between the two types of items (Figure 7.4.1). In contrast, hippocampus can support such differentiation. Hippocampus learns by assigning separate detailed representations to every bit of the incoming information. On Y/N tests with related lures, it can support recognition memory because lures can first trigger the reconstruction of the stored hippocampal representation and subsequently be rejected on the basis of the mismatch between the retrieved information and the cue (recall-to-reject strategy). Thus, on Y/N tests with similar lures hippocampal recollection supports recognition better than does so familiarity.

Instead, when given a FC test, participants while still having a possibility to solve the task on the basis of recollection, receive an opportunity to do that by means of familiarity, too. As 7.4.1 shows, familiarity of the studied items would always be slightly higher than that of unstudied items, and due to a high degree of covariance in target and lure familiarity distributions, even small differences in the familiarity of studied and lure representations become reliably informative (Migo et al., 2009; Holdstock et al., 2002; Norman & O'Reilly, 2003). Thus, on every trial participants can simply compare the strength of the familiarity signal triggered by targets and similar lures and accept an item with a higher familiarity strength as old.

Associative recognition experiments are thought to constitute a special case of recognition tests with a related lure paradigm (Norman & O'Reilly, 2003). In the case when word pairs A-B and C-D were studied, a rearranged pair A-D yields a representation overlapping with that of studied pairs. Following the mechanism described above, standard associative recognition tests that

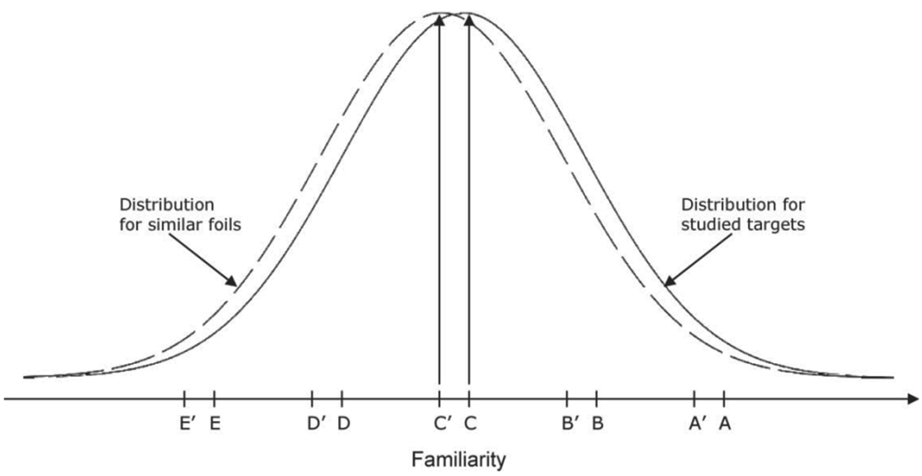


Figure 7.3: Taken from Migo et al. (2009). Figure shows familiarity disctributions for studied items (A, B, C, D) and similar foils (A', B', C', D'). Because the two bell-shaped distributions highly overlap, it is not possible to set a response criterion on the familiarity axis that would allow to reliably discriminate between studied items and lures in a Y/N recognition task. Assessing small differences between targets and lures in each trial of the FC test, however, enables successful discrimination between the two types of stimuli.

ask participants to identify each word pair as either being old, rearranged or new pairs would often stimulate participants reliance on recollection, whereas FC tests (AB or AD?) might promote solving the task on the basis of familiarity of the association (Norman & O'Reilly, 2003; Clark et al., 1993; M. M. Patterson & Hertzog, 2010). For all this evidence, I assume that Experiment 2 that used an FC format provided participants with additional opportunity to solve a recognition task on the basis of familiarity. Experiment 2 clearly shows under the FC test format familiarity supported associative recognition of the thematically related pairs to a greater extent than of categorically related ones, though I acknowledge that other aspects of experimental procedure could have contributed to this outcome, too (discussed further).

7.4.2 INDICATIONS OF AN ASYMMETRIC PATTERN OF R- AND K- RESPONDING IN THE THEMATIC AND CATEGORICAL CONDITIONS

As mentioned above, Experiment 2 targeted at assessing potential differences in the levels of familiarity-based recognition. It nonetheless merited exploring whether the data might contain some indication of differential involvement of recollection in the recognition of the two relation types. Overall analysis of the proportion of R-responses suggested that recollection seemed to make a similar contribution in the categorical and thematic conditions. Differences between the conditions, however, were found when participants were split into two groups: those with a higher response accuracy in the categorical than thematic condition and those with a higher accuracy in the thematic than categorical condition. Comparing proportions of R and K responses in the categorical and thematic conditions within each group, indicated that those participants who performed better in the categorical condition, respond more often of the basis of recollection in the categorical than in the thematic condition. No differences in K responses were observed. This was not the case for the "thematic preference" group in which participants showed a higher K-based recognition rate in the thematic than categorical condition, with no differences in R-responses. These observations tentatively imply that high performance in the categorical condition might be linked to an active engagement of recollection, whereas more accurate responding in the thematic condition might be related to the degree of the involvement of familiarity.

Additionally to that, correlation analyses showed a positive linear relationship between R-based hit rate and overall accuracy in the categorical condition and K-based recognition and overall accuracy in the thematic condition. They showed that increasing reliance on recollection as a retrieval process irrespective of relation was associated with an increase in recognition accuracy in the categorical but not in the thematic condition. In contrast, more extensive engagement of familiarity in the old-rearranged discrimination seems to be associated with higher performance in the thematic but not in the categorical condition. These results complement well the pattern observed in Experiment 1 and suggest an asymmetric pattern of recollection/familiarity engagement in recognition of the thematic and categorical pairings.

7.4.3 DUAL-PROCESS vs. SINGLE-PROCESS MODELS INTERPRETATION OF THE DATA

Reaction times associated with correctly recognized items were also analyzed. Shorter RTs were observed for R- than K-judgments, suggesting that processes underlying R- and K-based recognition are temporally dissociable. This finding, though a replication of previous results (Vilberg et al., 2006; Vilberg & Rugg, 2009; Dewhurst, Holmes, Brandt, & Dean, 2006; Rotello & Zeng, 2008) might be thought as contradicting the DPSD model of recognition memory which assumes that familiarity acts faster than recollection (see Chapter 1, Yonelinas, 2002). A number of researchers suggested that this pattern of RT results delivered by an RK paradigm is more consistent with single-strength models of recognition memory (Dewhurst et al., 2006; Rotello & Zeng, 2008). Nonetheless, the data can still be accounted for by dual-process models. One possibility is that such an outcome results from participants misinterpreting the test instructions as encouraging them to respond on the basis of K or G only if recollection failed (Yonelinas, 2002). It is also possible that longer recognition RTs associated with subsequent K and G responses simply reflect that while not being able to recollect the study episode participants repeated their attempts to do so, thus delaying their recognition decision (for a similar explanation see Vilberg et al., 2006). I acknowledge, however, that the present RT data does not allow to discard the single-strength account models of the findings. Nonetheless, two other data points are informative with regard to this issue.

As described in detail in Section 1.3.1, single-process models interpret the RK responses as rather reflecting different degrees of memory strength or confidence than distinct mnemonic processes with K responses corresponding to weaker memories and less confident recognition responses than R responses (Dunn, 2004; Wais et al., 2008; Rotello & Zeng, 2008; Wixted, 2009). From this perspective, the data of Experiment 2 suggests that recognition of the thematic pairs was accompanied by a lower degree of confidence than that of the categorical pairs. However, provided lower confidence yields poorer hit rates (Busey, Tunnicliff, Loftus, & Loftus, 2000), the single strength account of the data appears somewhat dubious as comparable levels of performance were achieved in both conditions. The same problem for the single-strength models is posed by the data of the two participant groups. In the thematic preference group, higher recognition accuracy in the thematic condition was associated with higher K-values than in the categorical condition. These two findings undermine the single-process models' evaluation of the results speaking for a dual-process interpretation of the data.

7.4.4 EFFECTS OF VARIOUS ASPECTS OF EXPERIMENTAL PROCEDURE ON THE OUTCOME OF EXPERIMENT 2

The data of Experiment 2 suggested that participants engaged recollection more than familiarity irrespective of relation. High hit-rates and a high proportion of R-based responses collectively suggest that participants could well recognize the studied pairs and retrieve details about corresponding study episodes in the categorical and thematic conditions. It is therefore possible that in Experiment 2 participants showed "ceiling effects" in recognition performance which consequently made potential differences in the contribution of recollection undetectable. The following several aspects of the procedure of Experiment 2 could have boosted recognition memory and supported high levels of recollection-based responding in both conditions.

Firstly, the effect might be attributed to subdividing the experimental procedure into five relatively short study-test blocks with each study-test phases separated by a 1-minute retention interval. This was done on the basis of pre-experimental piloting in order to achieve above chance levels of correct recognition. Furthermore, as items that are recognized on the basis of familiarity after short retention intervals are forgotten more rapidly than items recognized on the basis of recollection as evidenced by a more profound drop in accuracy of familiarity-based recognition than recollection-based discrimination at longer retention intervals (Yonelinas, 2002; Dudukovic & Knowlton, 2006), we aimed at reducing the study-test lag to obtain a reasonable number of K-responses. At the same time, shortening the retention intervals between study and test and reducing the length of the study-phase item lists could have affected recollection-based recognition. A number of prior studies indicate an inverse relationship between the duration of the retention interval and levels of recollection-based remembering. For example, (Herron & Wilding, 2005) manipulated the retention interval in an ERP study in which a test phase followed a study either immediately or after a 40-minute retention interval. The results showed increase in performance and in recollection-levels as evidenced by recognition accuracy and a larger ERP late-parietal old/new effect in the no-delay compared to the delay condition. Other experiments (Wilding, Fraser, & Herron, 2005) directly manipulated the length of study-test lists in an exclusion task and showed that shorter study-test blocks yield superior memory accuracy and a better control over recollection by strategically directing it to the retrieval of the task-relevant information. For the present data, the above findings imply that a short study-test retention interval and a small set size of each study-test block in Experiment 2 could have elevated recognition accuracy and recollection-based responding in both conditions to such a degree that it was impossible to observe any differences between categorical and thematic conditions. In addition this could have enabled participants to exert a considerable control over recollection-based recognition such that the differences in the reliance on recollection due to stimulus-driven effects could have been masked by the strategic engagement of this process.

Secondly, compared to Experiment 1, Experiment 2 set relatively relaxed temporal demands on the recognition task. In the test phase of Experiment 1, a word pair was presented for a short duration (800ms) followed by a display prompting participants to make a recognition decision and possibly functioning akin to a response-deadline. In contrast, in Experiment 2, words remained on the screen throughout the time window given for the recognition decision, possibly reducing time pressure on the task. Numerical comparison of the reaction times of correct responses in Experiments 1 and 2 suggests that participants indeed took longer to respond in Experiment 2. As mentioned in Chapter 1, recollection is conceptualized as a relatively slow mnemonic process (Yonelinas, 2002; Eichenbaum et al., 2007; Rugg & Curran, 2007) with various types of detailed information about the study episode being available later than simply information about previous occurrence of an item (Johnson, Kounios, & Reeder, 1994; Hintzman et al., 1998). It is therefore conceivable that providing participants with a relaxed response window could have given them time to gradually recollect various content information about the study episode and, as discussed above, for items that did not immediately elicit recollection to reiterate recollection attempts until either succeeding in retrieving details of the study episode or providing a K/G-judgment.

The third aspect that could have likewise boosted recognition accuracy and recollection-based recognition is the manner of word pair presentation at study. In Experiment 2, paired words were presented simultaneously and remained on the screen throughout the imagery task which led to a prolonged perceptual exposure to the stimuli and possibly to a deeper encoding of the two words as a pair. Vilberg and Rugg (2009) demonstrated that a longer item presentation during the study phase leads to an increase in recollection as indexed by a higher R-based hit rate and to a larger left parietal old/new effect in the long compared to short encoding condition. Thus, introducing simultaneous word pair presentation instead of the sequential one as in Experiment 1, could have contributed to a more profound encoding of studied information and consequently to a boost of recollection-based remembering.

7.5 CONCLUDING REMARKS

Taken together, results of Experiment 2 complement findings of Experiment 1 by showing that the type of pre-existing semantic relation between the paired concepts impacts the degree to which familiarity and recollection are engaged in associative recognition memory. Experiment 2 demonstrated that under such testing conditions that enable solving an associative recognition task both on the basis of recollection or familiarity, recognizing thematically related word pairs is more likely to be achieved by means of familiarity than recognizing categorical pairs. Supporting the outcome of Experiment 1, results of Experiment 2 also provide tentative evidence for a more critical role of recollection in the recognition of categorical than thematic pairs.

CHAPTER 8

EXPERIMENT 3

8.1 INTRODUCTION

As described in Chapter 4, cross-cultural research pointed to putative differences in relevance of semantic relations for the performance on certain tasks. To recapitulate, according to some reports (Unsworth & Pexman, 2005) the type of semantic relation (categorical vs. thematic) does not modulate performance in categorization and priming tasks in East Asian participants, whereas it does so in Western participants presumably reflecting differences in availability of categorical/thematic relations in semantic memory. Gutchess et al. (2006) made an observation that categorical information was less relevant for performance on a free recall task for elderly East Asian participants than for Western participants who actively used categorical clustering to aid recall. In contrast to these findings, Saalbach and Imai (2007) reported little differences between Westerners and East Asians in categorization tasks with different test instructions and in a priming experiment, implicating that information about categorical and thematic semantic relatedness might guide performance in various tasks in a similar way in East Asian and Western participants. The data of Saalbach and Imai (2007) thus speaks to the proposal of universal significance categorical/thematic relations to human conceptual structure and their effects on task performance.

Experiment 3 aimed to investigate whether these putative cross-cultural differences in making use of the semantic relational information might be reflected in the way familiarity/recollection are engaged in associative recognition of categorical and thematic pairs in East Asian participants as contrasted to German participants. For this purpose, Experiment 3 was conducted in China with native Chinese speakers. Experiment 3 was similar to Experiment 1: participants first studied categorically, thematically and unrelated filler word pairs. At test, they performed an associative recognition task discriminating between old, rearranged and new pairs. ERPs were recorded at test to tap into electrophysiological signatures of familiarity (the early frontal old/new effect) and recollection (the late parietal old/new effect). To obtain more trials contributing to grand-averages and by this reduce noise in the ERP data, participants performed two study-test sessions separated by a one week interval. Materials that were used in Experiment 1 were translated into Mandarin Chinese and were employed in Experiment 3 (see Appendix B).

The following predictions were made with respect to the outcome of Experiment 3:

- If information about categorical/thematic relations guides associative recognition memory in Chinese participants in a way similar to Germans, this should then lead to a modulation of behavioural and electrophysilogical mnemonic measures by the type of relation and the overall pattern of results should resemble that predicted for Western participants. Specifically, as for German participants, both familiarity and recollection are expected to contribute to associative recognition of the both types of semantic relations. Thematic relations due to their integrative nature are predicted to support familiarity-based recognition and attenuate the engagement of recollection (see Section 3.5 for more on predictions for Experiment 1).

- If information about the categorical/thematic relatedness does not actively contribute to performance on an associative recogntion test for Chinese participants, then relation type is not expected to modulate recognition performance or the involvement of familiarity and recollection. In this case, similar behavioural and electrophysiological patters should be obtained in the categorical and thematic conditions.

8.2 METHOD

8.2.1 PARTICIPANTS

Eighteen participants took part in Experiment 3. The data from two participants were discarded due to technical problems during the EEG recording. The remaining 16 participants (9 female) were all native Chinese speakers, right-handed, on average 22.72 years old (ranging from 20 to 25 years).

8.2.2 MATERIALS

Experiment 3 was designed such that to maximally closely mirror Experiment 1. Stimuli were selected according to the procedure described in Chapter 5. The way materials were assigned to experimental conditions in Experiment 3 was identical to that of Experiment 1 (see Section 9.2.2). Experiment 3 was conducted in Mandarin Chinese.

8.2.3 DESIGN AND PROCEDURE

EPrime software was used to implement the experiment. Stimuli were presented on a 19” monitor in black on a white background. Keyboard was used as an input device.

Design and procedure of Experiment 3 were largely identical to Experiment 1 (see Section 6.2.3) with the following adjustments to the duration of item presentation at study and test (marked in blue in Figure 8.1): during the study phase, each word was presented on the screen for 800ms and time given to perform a mental imagery task was 1400ms (respective timings in Experiment 1 were 400 and 1000ms). Changes to the timings of the procedure were undertaken after conducting a piloting study with a procedure used in Experiment 1. Presentation of items at study was increased to raise the levels of recognition performance above the chance level and following the feedback of the pilot participants that 400ms was not sufficient to read some words. Accordingly, word pair presentation time was adjusted at test. Total time given for performing an old/rearranged/new discrimination task remained the same as in Experiment 1, that is 3000ms. This duration incorporated 1600ms that a word pair remained on the screen (i.e. twice as much as presentation of each individual word at study) and 1400ms of a blank screen (compared to 800ms and 2200ms in Experiment 1).

8.2.4 DATA AQUISITION

Scalp voltages were recorded using 66-channel Quick Cap (Neuroscan) where silver/silver-chloride electrodes are placed into the cap according to the extended International 10–20 system (American Encephalographic Society, 1994). Left mastoid was used as a reference during the data collection but EEG was also recorded from the right mastoid to allow off-line rereferencing to linked mastoids. EOG electrodes were placed above and below the left eye and on the outer canthi of both eyes. Electode impedences were kept below 10 kΩ. Data were acquired with a bandpass from 0.05 Hz to 100 Hz and digitalized at a sampling rate of 500 Hz with a resolution of 16-bit using SynAmps amplifiers. Offline data processing included ltering with a band-pass finter from 0.05 Hz to 30Hz, identifyiny and correcting eye activity artifacts with independent component analysis (ICA) procedure (Jung, Makeig, Humphries, et al., 2000; Jung, Makeig, Westerfield, et al., 2000) using Brain Vision Analyzer software. The data were then imported into EEProbe for further processing. Continuous EEG signal was split into individual epochs of 1000ms each beginning 100ms before the onset of a word pair. All trials were visually inspected and rejected if they contained artifacts, i.e. whenever standard deviation in a 200ms time interval exceeded 30 V in either Cz or any of EOG channels. Grand averages were then computed for correct old and new responses. The mean number of artifact-free trials contributing to the analysis of test-phase ERPs of old and new pairs was 24 and 22 in the categorical condition, and 22 and 22 in the thematic condition. For the presentation purposes, the data was filtered with a low-pass filter set to 12Hz.

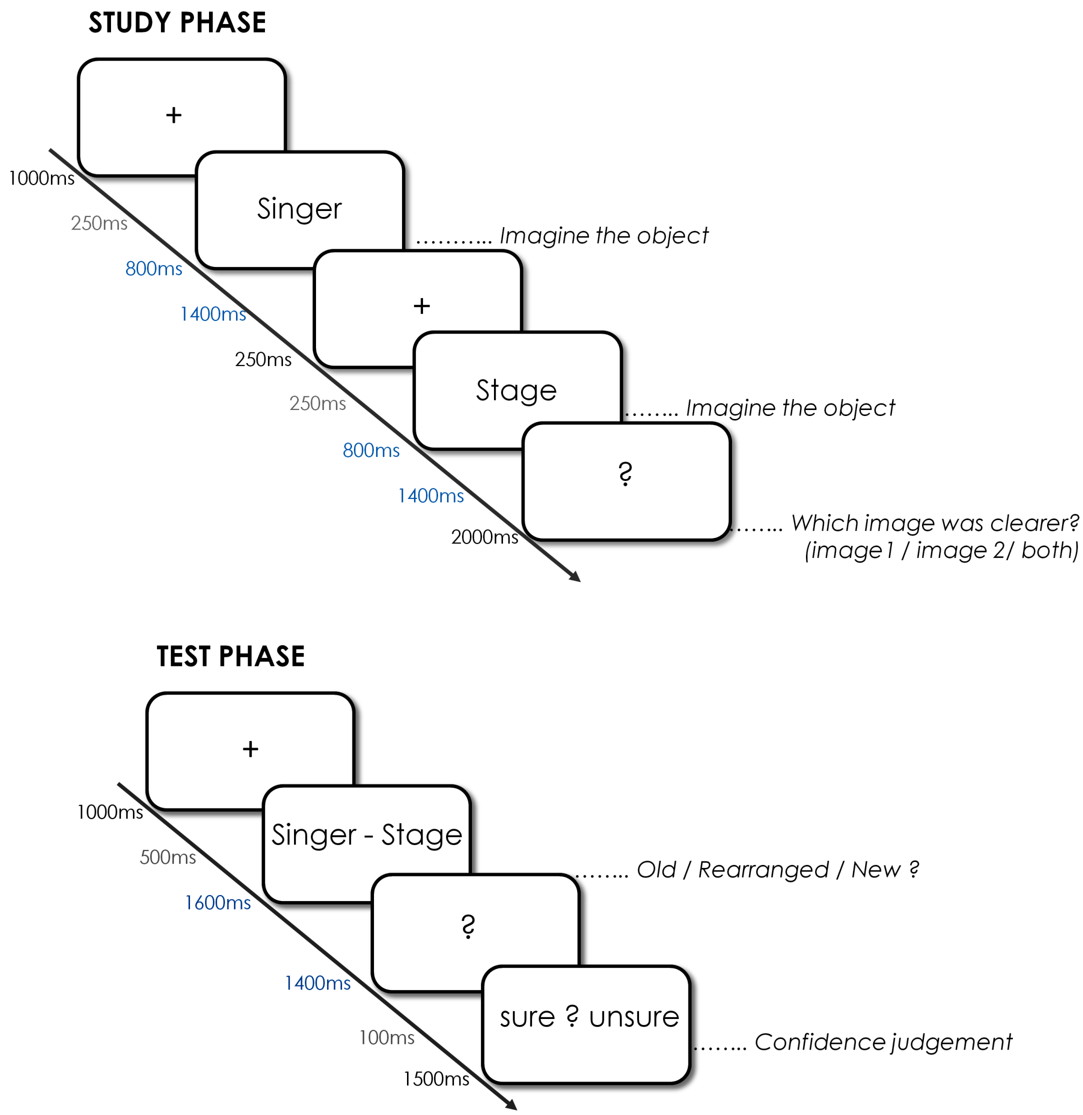


Figure 8.1: Experiment 3. Illustration of the experimental procedure: the upper pannel shows the trial procedure during the study phase; the lower pannel represents the trial procedure during the test phase. Highlighted in blue are the timings that deviated from those in Experiment 1

8.2.5 DATA ANALYSIS

In accordance with the expected topography of the early frontal and late parietal old/new effects, mean amplitudes associated with correct responses to old and new word pairs in the categorical and thematic conditions were computed from voltages recorded from the same eight electrodes as in Experiment 1: superior and inferior left frontal electrodes (F1, F3), right frontal (F2, F4), left parietal (F1, F3) and right parietal (P2, P4). Based on the existing knowledge about the time windows in which the effects of interest are to be observed (Rugg & Curran, 2007; Mecklinger & Jäger, 2009) and on the visual inspection of the data, early time window was restricted to 300-500 ms post-stimulus and the late time window was set to 500-650 ms. In the ERP analyses, unless specified otherwise, only effects involving factors Relation and Type, or interactions involving these factors are reported.

8.3 RESULTS

8.3.1 BEHAVIOURAL RESULTS

Behavioral results, collapsed across two experimental sessions[1], are summarized in Table 8.1. The table presents hit rates (Hit), correct rejection rates (CR), false alarm rates to new and to rearranged word pairs erroneously endorsed as old (FA old, FA rear), as well as old-new and associative Pr scores computed as described in Chapter 6.2.5. Reaction times associated with hits and correct rejections are also presented. As Table 8.1 shows, the pattern of the performance data of Chinese participants is similar to that elicited by German participants (to compare, see Table 6.3.1).

	HIT RATE	CR RATE	FA NEW	FA REAR	PR OLD-NEW	PR ASSOCIATIVE	RT	
							HIT OLD	CR
CATEGORICAL	.82 (.02)	.75 (.03)	.10 (.03)	.48 (.04)	.71 (.03)	.33(.04)	1446 (51)	1355 (45)
THEMATIC	.74(.02)	.74 (.03)	.10 (.02)	.41 (.05)	.64 (.02)	.34 (.05)	1491(50)	1384 (51)

Table 8.1: Experiment 3. Behavioural results. Mean hit rate, correct rejection rate, corresponding mean reaction times. Provided are false alarm rates associated with new word pairs erroneously endorsed as old (FA new) and false alarms to rearranged word pairs incorrectly accepted as old (FA old). The table also shows two types of Pr scores indexing old-new and associative discriminability (standard error)

As suggested by the data in Table 8.1, participants responded more accurately in the categorical condition. Statistically, this is also reflected in the main effect of Relation, $F(1, 15) = 7.423$, $p = .016$, revealed by a two-way ANOVA with factors Relation (categorical, thematic) and Type (Hit, CR). The analysis did not yield any effect of Type and no interaction between Relation and Type, both p-values $> .119$. Further, categorical and thematic conditions were compared with regard to participants' ability to discriminate between old vs. new pairs (old-new Pr score) and old vs. rearranged pairs (associative Pr). The results revealed higher old-new discriminability in the categorical than in the thematic condition, $t(15)=2.457$, $p = .027$, but no significant differences in the associative discriminability, $t(15) = .234$, $p = .818$. The loss of mnemonic advantage in the associative discriminability in the categorical condition was driven by a higher proportion of false alarms in the rearranged categorical than thematic condition, $t(15) = 3.403$, $p = .004$. No

[1]Collapsing the data across the two sessions was justified by the analysis of performance data that took factor Session into account. A three-way ANOVA with factors Relation (categorical, thematic), Type (Hit, CR) and Session (session 1, session 2) did not reveal any effect of Session and no interactions with this factor, all p-values $> .326$. Likewise, neither of the two-way ANOVAs with Factors Relation (categorical, thematic) and Session (session 1, session 2) conducted on the old-new and associative Pr scores revealed an effect of Session or interactions with this factor, all p-values $> .167$. Thereby, all further analyses were conducted on the data collapsed across the two experimental sessions.

differences were observed in the proportion of new items erroneously endorsed as old (FA new), $t(15) = .280$, $p = .783$.

ANOVA on the reaction times of correct responses to old and new items with factors Relation (categorical, thematic) and Type (old, new) suggested marginally faster responses in the categorical than in the thematic condition, $F(1,\ 15) = 4.235$, $p = .057$, and likewise marginally faster responses to new than old pairs, $F(1,\ 15) = 4.429$, $p = .053$. No interaction between the factors Relation and Type was observed, $F(1,\ 15) = .322$, $p = .579$.

To investigate whether participants correct responses to old and new items in categorical and thematic conditions differed in terms of response confidence, probabilities of "sure" responses to correct old and new judgments in categorical condition [mean values with standard error of the mean are .96 (.01) and .83 (.06), respectively] were compared with those to thematic ones [.95 (0.01) and .83 (0.06), respectively]. A two-way ANOVA with factors Relation (categorical, thematic) and Type (Hit, CR) revealed an effect of Type, $F(1,\ 15) = 4.977$, $p = .041$, suggesting that participants felt more confident about correctly endorsed old pairs than new ones. There was neither an effect of Relation, nor an interaction between Type and Relation, both p-values $> .364$.

8.3.2 ERP RESULTS

Visual inspection of electrophysiological data (Figure 8.3.3 , for an extended view of waveforms from 46 electrode sites see Figures D.1 and D.7 in Appendix D) suggested a highly similar pattern for categorical and thematic relations: old and new ERP waveforms did not diverge in the early time window, while were more positive going for hits than correct rejections in the late time windows, especially over the parietal locations. Separate analyses of the data from the two time windows aimed to test the observed pattern statistically.

8.3.3 EARLY TIME WINDOW: 300 – 500 ms

A four-way ANOVA with factors Relation (categorical, thematic), Type (Hit, CR), Location (frontal, parietal), Laterality (left, right) and Site (inferior, superior), conducted on the data from the early time window, provided no indication of the presence of early-frontal old/new effects. There was no effect of Type, Relation, or any interactions involving these factors, all p-values $> .095$.

8.3.4 LATE TIME WINDOW: 500 – 650 ms

Confirming the visual pattern of the ERP data in the late time window, the ANOVA with factors Relation (categorical, thematic), Type (Hit, CR), Location (frontal, parietal), Laterality (left, right) and Site (inferior, superior) uncovered a main effect Type, $F(1,\ 15) = 11.905$, $p = .004$, a Type by Location interaction, $F(1,\ 15) = 6.723$, $p = .02$, a marginally significant Type by Laterality, $F(1,$

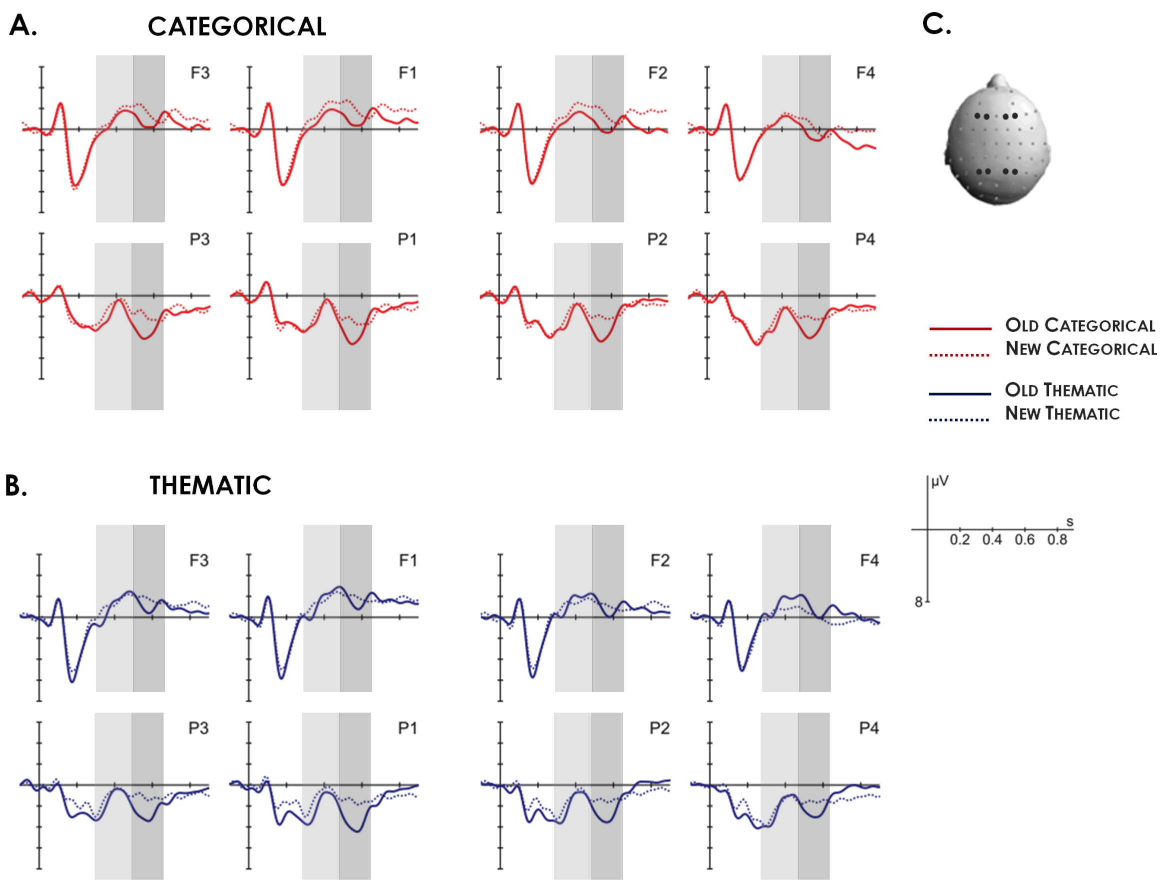


Figure 8.2: Experiment 3. Old/new effects observed during the test phase. (A) depicts grand average ERPs for correct old and new responses in the categorical condition. (B) depicts grand average ERPs for correct old and new responses in the thematic condition. (C) highlights the sites of electrodes (F3, F1, F2, F4 and P3, P1, P2, P4) included into analyses of the early and late old-new effects as viewed from above.

15) = 4.483, p = .077, and Type by Site interactions, $F(1, 15) = 3.758$, p = .072. All other effects and interactions with the factors of interest failed to reach significance, $p > .132$. To resolve Type by Location interaction, old/new contrasts were conducted on the data from the frontal and parietal regions collapsed across factors Relation, Hemisphere and Site. These contrasts revealed that new word pair ERPs were more negative than old pair ERPs on parietal locations, $t(15) = 4.689$, $p < .001$, but not on frontal locations, $t(15) = 1.538$, p = .145. In order to resolve a marginally significant Type by Site interaction, two paired old/new contrasts were computed on the data from the superior ROI (electrodes F3, F4, P3, P4) and the inferior ROI (electrodes F1, F2, P1, P2) collapsed across Relation. Both old/new contrasts were significant, $t(15) = 2.547$, p = .022 and $t(15) = 2.807$, p = .013. Old/new contrasts performed to resolve a marginally significant Type by Laterality interaction on the data from left (F1, F3, P1, P3) and right (F2, F4, P2, P4) hemispheres likewise collapsed across factor Relation yielded significant old/new differences on both left and right ROIs, $t(15) = 2.595$, p = .020 and $t(15) = 2.580$, p = .021.

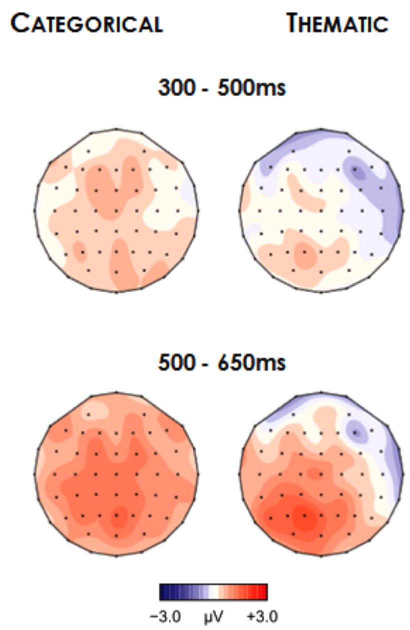


Figure 8.3: Experiment 3. Topographic maps showing the distribution of the early (300–500 ms) and late (500–650 ms) old/new effects separately for the categorical and thematic conditions.

8.3.5 UNRELATED DATA ANALYSIS

To check whether the observed pattern with a larger reliance on recollection across the two conditions was specific to related word pairs only, unrelated filler data were analyzed. First, behavioral analysis showed that participants were more accurate rejecting new items (CR, M = .7 (.04)) than correctly recognizing items as old (Hit, M = .53 (.03)), $t(15) = 3.038$, $p = .008$.

Visual examination of the unrelated ERP data recorded from the same 8 electrodes as in the related conditions (see Figure 8.3.5, and Figure D.8 in Appendix D) suggested the presence of the late parietal old/new effect only were analyzed (mean number of trials contributing to grand averages for hits and correct rejections was 16 and 22, respectively). Of interest for statistical analyses conducted on these data was an effect of Type and interactions involving this factor. A four-way ANOVA with factors Type (Hit, CR), Location (frontal, parietal), Laterality (left, right) and Site (inferior, superior) conducted on the voltages from the early time window, revealed significant three way interactions between factors Type, Laterality and Site, $F(1, 15) = 5.046$, $p = .04$, and Type, Location and Site, $F(1, 15) = 5.195$, $p = .038$. No main effect and no further interactions with factor Type were found, all p-values $> .153$. To resolve the interaction between factors Type, Location and Site, the data were collapsed across factor Laterality and pairwise old vs. new contrasts were conducted on the data of each of the four separate ROIs: frontal inferior; frontal superior; parietal inferior and parietal superior. The results yielded marginally significant old/new differences at inferior and superior parietal ROIs, $t(15) = 1.980$, $p = .066$, and $t(15) = 1.994$, $p = .065$, respectively, but not on frontal ROIs, both p-values $> .397$. Further, Type by Laterality by Site interaction was resolved by collapsing the data across factor Laterality and running old/new contrasts on the data from left inferior, left superior, right inferior and right superior ROIs. The

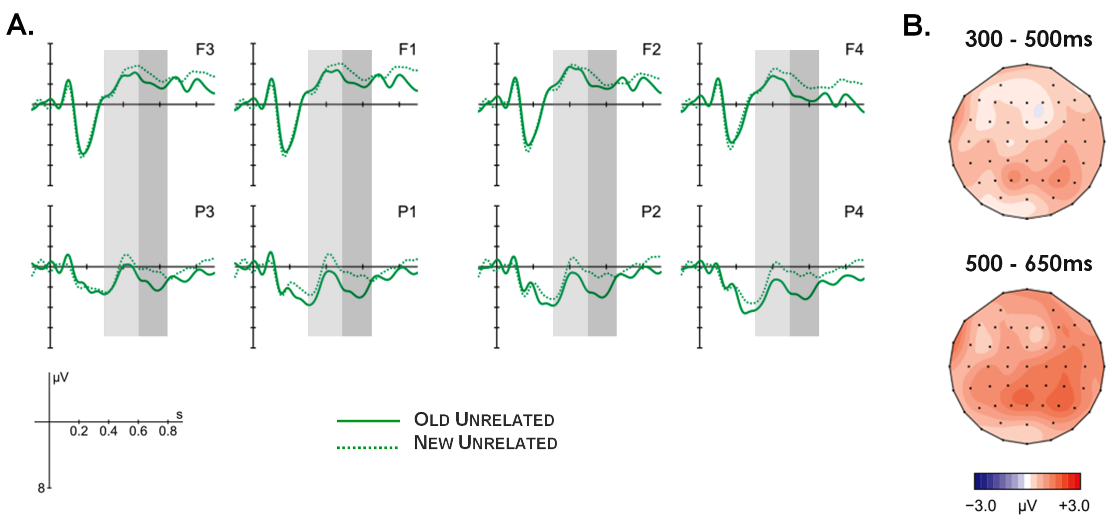


Figure 8.4: Experiment 3. Old/new effects elicited by correct old and new responses in the unrelated condition. Panel A shows ERP waveforms and panel B depicts corresponding topographic distribution of old minus new differences in the early (300-500ms) and late (500-650ms) time windows.

results yielded pronounced old/new differences on the right inferior ROI, $t(15) = 2.384$, $p = .031$, while other contrasts did not turn out significant, all p-values $> .215$.

The three-way ANOVA on the data from the late time window revealed a main effect of Type, $F(1, 15) = 5.970$, $\mathrm{p} < .02$, and interactions between Type, Laterality and Site, $F(1, 15) = 10.388$, $p = .006$, and Type, Location and Site, $F(1, 15) = 5.123$, $p = .039$, with other interactions involving factor Type failing to reach significance, all p-values $> .173$. Three-way interactions in the late time window were resolved in the same fashion as those in the early time window. When collapsing the data across the factor Laterality, paired contrasts turned out significant on inferior frontal, and on inferior and superior parietal ROIs, all p-values $< .05$. When collapsing the data across the factor Location, significant differences were uncovered on right and left inferior ROIs, both p-values $< .05$, and marginally significant – on both superior ROIs, both p-values $< .063$.

To check whether neural generators contributing to early and late old/new effects in the unrelated condition were different, topographic distributions of the old-new differences in the early and late time windows were compared. Old minus new subtraction values were normalized using vector-scaling procedure (McCarthy & Wood, 1985; Picton et al., 2000) and then submitted to a four-way ANOVA with factors Window (early, late), Location (frontal, parietal), Laterality (left, right) and Site (inferior, superior). Critically, there was no main effect of Window and no interactions involving this factor, all p-values $> .111$, which implicates that the early old/new effect was likely to reflect the early onsetting late parietal old/new effect.

8.4 DISCUSSION

Experiment 3 was conducted to investigate whether the type of semantic relation between paired concepts (categorical vs. thematic) modulates associative recognition memory in Chinese participants and whether this modulation is comparable to that of German participants. With some adjustments to the timing of the procedure, Experiment 3 was highly similar to Experiment 1. Behavioral measures and electrophysiological markers of associative recognition memory were collected. Building on the cross-cultural research on categorization and memory, two potential outcomes were predicted. If information about semantic relations is used by East Asians a way similar to Westerners (Saalbach & Imai, 2007), then categorical and thematic relations were expected to differentially modulate processes engaged in associative recognition in Chinese participants as reflected in the behavioural and electrophysiological measures. Familiarity was predicted to support recognition of thematically related pairs to a greater extent than recognition of categorically related pairs. In contrast, engagement of recollection in the associative recognition of the thematically related pairs should be attenuated (see Section 3.5). If semantic information is of less relevance to East Asian participants than to Western participants (Unsworth & Pexman, 2005; Gutchess et al., 2006), then no modulation of associative recognition memory by categorical and thematic relations was to be found.

Analysis of the performance data revealed that Chinese participants were more likely to correctly recognize intact and correctly reject new word pairs in the categorical than thematic condition, as suggested by the analyses of Hit and CR-rates, as well as old-new Pr scores. This consistent advantage in the categorical condition was eliminated when ability to discriminate between old and rearranged pairs (associative Pr) was compared: a higher proportion of false alarms in the rearranged categorical condition suggested that participants experienced more difficulties in telling apart rearranged and old pairs in this condition as compared to the thematic. In sum, behavioural data of Experiment 3 had a strong correspondence with a pattern obtained in Experiment 1 with German participants by this providing preliminary evidence that information about the type of relation between paired associates guides recognition performance also in Chinese participants as would be expected according to the universal significance view of conceptual relations advanced by Saalbach and Imai (2007).

In contrast to that, assessing electrophysiological data offered no indication of modulation of associative recognition processes by the type of semantic relation: no old/new effects were observed in the early time window, whilst robust old/new differences were found on parietal locations in the late time window in both condition. These results raised a possibility that regardless of the type of semantic relatedness, recollection was a primary ("default") process supporting associative recognition in Chinese participants. This inference was further emphasized by the analyses of the data from the unrelated filler condition which revealed a presence of broadly spread old/new effects in the late time window. Though old/new differences were observed already in the early time window at parietal location, similar scalp distributions of the two effects suggest that the early differences marked an early onset of the late old/new effect relating to recollection.

Comparing the results of Experiments 1 and 3 implicates that in German participants, the nature of semantic relation is an important determinant of the extent to which associative recognition was supported by familiarity or recollection. In contrast, results of Experiment 3 indicate that categorical and thematic relations might not modulate associative recognition processes in Chinese participants: no matter what the type of relation between to-be-remembered concepts is, recognizing association of a previous occurrence appears to strongly rely on recollection in Chinese participants. Failing to observe a larger contribution of familiarity to associative recognition in either of the related conditions as compared to the unrelated in Chinese participants questions the generalizability of the proposal by Greve et al. (2007) that semantic relatedness between items fosters familiarity-based associative recognition. Apart from that, similar patterns of electrophysiological data in the categorical and thematic condition provide little support for the idea of universal significance of categorical and thematic relations and their similar impact on task performance across cultures (Saalbach & Imai, 2007). Thereby, the absence of the electrophysiological differences could be interpreted as supporting the idea that semantic relatedness might not guide task performance in East Asians as it does in Westerners (Unsworth & Pexman, 2005) and (Gutchess et al., 2006) and the nature of conceptual relations has no effect on the processes supporting associative recognition.

Nonetheless, modulation of behavioural measures by relation type and its similarity to behavioural results of Experiment 1 tentatively point to an importance of relational information for performance on associative recognition task and indicate that there might be some other explanations for the exclusive reliance on recollection by Chinese participants. One way to account for a considerable contribution of recollection to associative recognition in Chinese participants is to relate it to the extended encoding times in Experiment 3 as compared to Experiment 1. Prolonging exposure to a stimulus at encoding is known to increase subsequent recollection (Vilberg & Rugg, 2009; Yonelinas, 2002). This, in turn, opens a possibility that recollection was so much boosted by additional encoding time that any differences in its engagement between different relations were masked. However, previous research that manipulated encoding times typically used larger temporal differences between short and long exposure conditions, e.g., 5sec in a study by Vilberg and Rugg, leaving it unclear whether a difference of 800ms could have considerably boosted recollection. In addition, attributing active engagement of recollection entirely to the effects of extended encoding seems to be somewhat dubious given that recognition accuracy in Chinese was not at the ceiling. Moreover, increased encoding time does not explain why no correlate of familiarity for either of the related conditions relative to the unrelated filler condition was found. In light of this, it seems unlikely that encoding time differences alone could explain discrepancies between ERP patterns in Experiments 1 and 3.

Another possibility is to attribute a strong engagement of recollection in associative recognition of all relation types to the effect of specific testing paradigm. Old/rearranged/new discrimination task assumed to demand a strong contribution of recollection (see Section 7.4.1 for a detailed review on the issue Migo et al., 2009; Norman & O'Reilly, 2003) could have pushed Chinese participants to strategically engage recollection irrespective of relation type. If this is the case, changing the testing paradigm to one that encourages participants to more flexibly recruit familiarity and recollection-based recognition, should allow to observe the asymmetry in the engagement of familiarity/recollection in recognition of different types of relations. Experiment 4 was designed to address this issue.

8.5 CONCLUDING REMARKS

To conclude, the pattern of electrophysiological results obtained in Experiment 3 with Chinese participants was different from the German data of Experiment 3 in that it provided no indication for differential modulation of familiarity and recollection in associative recognition in Chinese participants. Irrespective of relational information, recollection appeared a dominant process supporting performance on associative recognition task requiring old/rearranged/new discrimination. Nonetheless, recognition performance was affected by the type of relation in Chinese participants. Correspondence of the behavioural patters of Chinese and German results offered a possibility that information about semantic relations modulates associative recognition memory in Chinese participants, but the effect was concealed due to the rigid requirement of the test format to rely on recollection during recognition. A change of the test format in Experiment 4 aimed to explore this possibility.

CHAPTER 9

EXPERIMENT 4

9.1 INTRODUCTION

In Experiment 3, contrasts between correct responses elicited by old and new word pairs showed reliable differences only at parietal locations in the later time window in the categorical and thematic conditions suggesting a critical contribution of recollection to associative recognition irrespective of the type of relation between the paired associates in Chinese participants. As was proposed in the discussion of Experiment 3, it is possible that East Asians unlike Westerners do not exploit information about the nature of semantic representations to guide the choice of the cognitive processes used to fulfill the associative recognition task and simply adhere to the same "default" process regardless of the type of semantic relation. Moreover, the results of Experiment 3 provided no indication of the early-frontal old/new effect for the either type of semantically related word pairs compared to unrelated ones indicating that previous findings demonstrating that semantic relatedness promotes familiarity-based recognition (Experiment 1; see also Greve et al., 2007; Opitz & Cornell, 2006; Rhodes & Donaldson, 2008) might not be universally generalizable across cultures.

It is yet feasible that this similar for all three conditions recollection-based pattern is limited to a specific task used in Experiment 3. Recognition task of a Yes/No format could have urged participants to adapt recollection-based recall-to-reject strategy (Migo et al. (2009); Norman and O'Reilly (2003); see also Chapter 7.4.1 for a detailed discussion on the issue) to such an extent that any kind of asymmetry in the engagement of mnemonic processes was eliminated. An important step in this regard is to investigate whether this pattern would persist in a more flexible recognition task that does not endorse a recall-to-reject strategy but allows to rely both on recollection and familiarity. Such opportunity is created by recognition tasks of a forced-choice format in which participants can directly compare familiarity strength of the two word pairs and accept the one with a higher signal strength as old, or meet their decision by recollecting details of the study episode (Norman & O'Reilly, 2003; Clark et al., 1993; M. M. Patterson & Hertzog, 2010).

In order to determine whether different types of semantic relations might modulate associative recognition processes in a forced-choice recognition task in East Asian participants, Experiment 4 that was almost identical to Experiment 2 was conducted with Chinese participants. As in Experiment 2, engagement of familiarity and recollection was estimated using the RK procedure (Tulving, 1985). If different types of relational information do impact associative recognition, then a forced-choice task should allow to tap into:

- asymmetries in the proportion of R and K responses in the categorical and thematic conditions. As for German participants, due to the integrative nature of the thematic relation that is to promote familiarity-based recogntion, a higher K response rate and attenuated R-based recogntion were predicted for the thematic compared to the categorical condition (see Experiment 2 for a similar prediction).

- effect of semantic relatedness as such on associative recognition in Chinese participants. To investigate whether semantic relatedness irrespective of its type might foster familiarity-based associative recognition (Greve et al., 2007) in Chinese participants, unrelated word pairs were included to enable the contrast. Higher K-based recognition of the semantically related compared to unrelated pairs was expected.

9.2 METHOD

9.2.1 PARTICIPANTS

Twenty-four participants (11 female) took part in Experiment 2 for payment or course credit. All were native Chinese speakers studying at Peking University, right-handed, on average 23 years old (ranging from 19 to 25 years).

9.2.2 MATERIALS

Experiment 4 employed a translated into Mandarin Chinese version of stimuli from Experiment 2 conducted in Germany (Chapter 7).

9.2.3 DESIGN AND PROCEDURE

The experiment was in general identical to German Experiment 2 with several adjustments to the timing procedure that were appeared necessary based on the pre-test data in order to keep test-performance comparable to Experiment 2 (Figure 9.1). At the study phase, word pairs were presented not for 2000 ms, but for 3000 ms. At test, participants had 3000ms for the forced-choice recognition decision, 2500ms for a Remember-Know-Guess response, i.e. 500 ms and 700 ms longer than for the corresponding responses in Experiment 2. All other details regarding the procedure were the same as in Experiment 2.

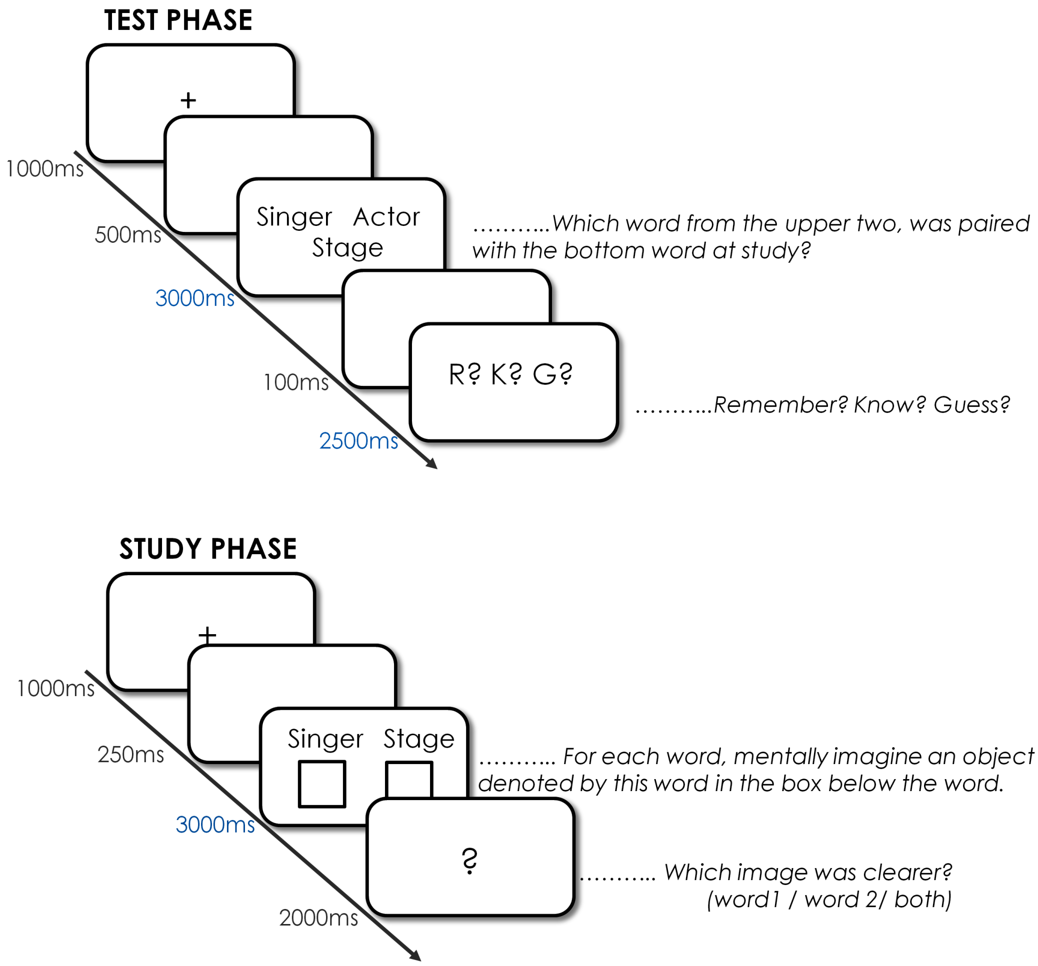


Figure 9.1: Experiment 4. Illustration of the experimental procedure: the upper pannel shows a trial procedure during the study phase; the lower pannel represent trial procedure during the test phase. Highlighted in blue are the timings that deviated from those in Experiment 2

9.2.4 DATA ANALYSIS

Prior to conducting statistical analyses, hit-rates, correct rejection rates, as well as estimates of familiarity, recollection and guessing were computed as described in Section 7.3.

9.3 RESULTS

Table 9.3 summarizes the results of Experiment 4. Recognition accuracy mirrored in hit-rates was modulated by the type of Relation (categorical, thematic, unrelated), $F(2, 46) = 14.453$, $p < .001$, $epsilon = .787$. This effect was driven by a higher proportion of accurate responses in the categorical condition than in the thematic condition, and by a higher accuracy in each of the related conditions compared to the unrelated, all p-values $< .014$. Reaction times associated with correct responses were likewise modulated by Relation, $F(2, 46) = 8.660$, $p = .001$, $epsilon = .827$, because recognition responses were significantly faster for both types of related word pairs than for unrelated, both p-values $< .026$.

	HITS	RT	HITS		
			R	K	G
CATEGORICAL	.81 (.02)	1747 (43)	0.70 (.03)	.35 (.04)	.19 (.02)
THEMATIC	.78 (.02)	1772 (41)	0.57 (.03)	.33(.04)	.19 (.02)
UNRELATED	.66 (.03)	1866 (42)	0.42 (.04)	.27(.03)	.25 (.03)

Table 9.1: EExperiment 4. Mean hit rate, corresponding reaction times, as well as R, K and G rates associated with correct responses (standard error)

Further analyses were guided by an intention to compare estimates of recollection, familiarity and guessing associated with correct responses (Table 9.3). At the first step, a two-way ANOVA with factors Relation (categorical, thematic, unrelated) and Process (recollection, familiarity, guessing) was conducted on R-, K-, and G- hit rates revealing a main effect of Relation, $F(2, 46) = 9.544$, $p < .001$, a main effect of Process, $F(2, 46) = 40.914$, $p < .001$, and an interaction between Process and Relation, $F(4, 92) = 13.253$, $p < .001$. Next, separate analyses were conducted to resolve Relation by Process interaction by assessing the effect of Relation on R, K, and G responding in separate one-way ANOVAs. The analyses showed that the type of relation impacted upon recollection-based responding, $F(2, 46) = 47.649$, $p < .001$. As uncovered by separate pairwise contrasts, a higher proportion of R-responses was associated with the categorical condition than with thematic, and with either of the related conditions compared to the unrelated, p-values $< .001$. There was no effect of Relation on guessing, $F(2, 46) = 2.284$, $p = .113$, or familiarity-based recognition, $F(2, 46) = 2.135$, $p = .130$. Helmert contrasts conducted on the K-responses to test the hypotheses that less K-responses should be associated with the unrelated condition compared to the semantically related ones and more K-responses should be associated with the thematic than categorical condition, confirmed the first prediction, $F(1, 23) = 3.974$, $p = .058$, but provided no indication for the second one, $F(1, 23) = .162$, $p = .691$.

With regard to the critical contrast between categorical and thematic relations, it is possible that the higher involvement of recollection in the categorical condition is just a mere consequence of the increased recognition accuracy in this condition. To address this possibility, I equated the performance in the categorical and thematic conditions, $t(19) = 1.393$, $p = .181$, by excluding the data from five participants – those for whom the difference between categorical and thematic hit-rates was .16 or larger. Even with equated performance, the pattern of results remained the same: whereas no significant differences were observed between the categorical and thematic conditions regarding familiarity- and guess-based recognition, both p-values $> .294$, recollection-based recognition was significantly higher in the categorical than in thematic condition, $t(14) = 3.121$, $p = .018$, implying that stronger reliance of recollection in categorical condition was not a consequence of a higher hit-rate.

9.4 DISCUSSION

Previous experiment (Experiment 3) indicated that regardless of the type of semantic relation (categorical or thematic), Chinese participants relied on recollection when performing an associative recognition task in which old, rearranged and new word pairs were to be discriminated. Whether or not paired associates were semantically related or not likewise did not play a role: there was no indication of the enhancement of familiarity for either type of related pairings. There are several possibilities to account for the results. First, the results might reflect that information about the type of semantic structure does not impact upon processes engaged in associaitve recognition in Chinese participants. Alternatively, the results might be simply a consequence of strategic reliance on recollection, as demanded by an associative recognition task of a YN format. Experiment 4 was conducted to differentiate between these two possibilities by creating such experimental conditions that would more likely promote flexible engagement of familiarity/recollection in associative recognition (FC test format). If semantic relations do impact associative recognition processes in Chinese participants and the absence of modulation in Experiment 1 is a mere consequence of a specific test format employed, then differences in R- and K- response rates between categorical, thematic and unrelated conditions should be observed in Experiment 4.

Contrasting accuracy of recognition responses showed that as in Experiment 3 participants were more likely to correctly recognize old categorical than thematic pairs. The critical finding of Experiment 4 was that semantic relations impacted upon the relative contribution of mnemonic processes to associative recognition. Engagement of familiarity indexed by the proportion of K-judgments following accurate recognition responses did not differ between the conditions, as neither did reliance on guessing. Critically, a higher proportion of R-responses was associated with correct recognition of categorically than thematically related pairs. It is noteworthy that this result did not reflect a better performance in the categorical condition: when equating performance by discarding the data from five participants, the pattern of results persisted. This suggests that participants could successfully recognize thematically related word pairs even though engaging less in the effortful recollection process whereas recognition in the categorical condition demanded stronger contribution of recollection. This outcome is consistent with the effect of the structure of semantic relations on recollection observed in Experiments 1 and 2 with German participants which both pointed to a higher engagement of recollection in associative recognition of the categorically related pairs.

An unexpected result of Experiment 3 was the absence of an electrophysiological marker or familiarity-based recognition in the categorical and thematic conditions that undermined the proposal that semantic relation between paired concepts serves as an organizing structure enabling familiarity-based recognition (Greve et al., 2007)(see also results of Experiment 1). To determine whether differences in familiarity-based associaitve recognition of arbitrary vs. semantically related associates might be observed in a task of the FC format, correctly recognized unrelated pairs were contrasted with the related ones regarding the proportion of associated K-responses. In accord with the proposal by Greve et al., the results suggested that word pairs marked by a presence of semantic relation are more likely to be recognized on the basis of familiarity than unrelated pairs by Chinese participants.

Overall, these results of Experiment 4 provide first evidence that semantic information modulates engagement of associative recognition processes in Chinese participants. As will be explained in detail in Section 10.2.1 of General Discussion, the pattern of the modulation can be accounted for from the perspective of differences in the nature of representations underlying thematic and categorical relations in a similar fashion as the results of the two German experiments. Therefore, the results of Experiment 4 can be cautiously taken as supporting the proposal of Saalbach and Imai (2007) by pointing to a universal effect of semantic relational structures on associative recognition memory.

Comparison of the German and Chinese data across all four experiments, however, points that the impact of semantic relational information on associative recognition memory in Chinese participants might be more strongly contingent on a test format. Whereas semantic relational information impacted on involvement of mnemonic processes in German participants in both experiments, for Chinese participants the effect was pronounced only under the FC format. Considering that recollection is widely assumed to be a main processes supporting associative recognition in general (Yonelinas, 2002; Mecklinger & Jäger, 2009; Mayes et al., 2007) and especially in tests of a Y/N format (Norman & O'Reilly, 2003; Clark et al., 1993; M. M. Patterson & Hertzog, 2010), it appears that when a test format poses a strong demand on the engagement of recollection, Chinese participants do not exploit differences in the nature of relational information to adjust the engagement of familiarity/recollection and simply adhere to the required and most suitable recognition process – recollection (Experiment 3). Conversely, when a test format (FC) allows more flexibility in engaging different recognition supporting processes (Norman & O'Reilly, 2003; Clark et al., 1993), semantic information can guide contribution of familiarity/recollection to associative recognition. The findings of robust electrophysiological signatures of recollection regardless of the relation type in Experiment 3 and the primary impact of relational information on the levels of R-based responding in Experiment 4 also point to the importance of recollection is the main "default" process in associative recognition in Chinese participants.

9.5 CONCLUDING REMARKS

Taken together, the results of Experiment 4 indicate that for Chinese participants semantic structure modulates processes contributing to associative recognition when it is probed under the forced-choice format, i.e. under conditions that allow more flexibility in relying on recollection and familiarity during recognition. Complementary to German data, the results of Experiment 4 indicate a higher contribution of recollection to recognition of categorical associates, thus pointing to some commonalities in the way semantic relations might modulate associative recognition in Western and East Asian participants. The findings suggest that as for German participants, information about the type of semantic relation guides associative recognition processes, albeit by impacting in the first turn on recollection. Moreover, Experiment 4 shows that familiarity supports associative recognition of related word pairs more than of unrelated in Chinese participants speaking for the proposal about the impact of semantic relatedness of recognition memory advanced by Greve et al. (2007).

CHAPTER 10

GENERAL DISCUSSION

A body of previous research has shown that the presence of long-standing semantic relations between paired concepts impacts episodic associative recognition memory (Naveh-Benjamin et al., 2005; M. M. Patterson et al., 2009). Several ERP reports demonstrated that whereas associative recognition memory of arbitrarily paired concepts (e.g. D. I. Donaldson & Rugg, 1998) primarily relies on recollection, the presence of a plausible categorical or thematic relation between the paired associates enables familiarity to play a role, too (Greve et al., 2007; Opitz & Cornell, 2006). To the best of my knowledge, no one has, however, explicitly compared how these types of conceptual relations modulate processes engaged in associative recognition memory. This issue was the primary focus of the present thesis, directly addressed in Experiments 1 and 2 conducted with German participants. Given differences in the nature of semantic representations underlying categorical and thematic relations (Estes et al., 2011; Lin & Murphy, 2001; Sachs et al., 2008), the critical assumption behind the comparison was that the holistic nature of thematic associates, namely the capacity of being integrated into a joint representation of a thematic scenario (Wisniewski & Bassok, 1999), might enhance the contribution of familiarity to and simultaneously reduce the involvement of recollection in associative recognition of relations of this type.

Another direction pursued in the thesis had a cross-cultural basis in its core. The rationale for following this direction was an assumption that there might be cross-cultural differences in making use of semantic relational information when solving various cognitive tasks, specifically that it might to a lesser extent (if at all) modulate performance in categorization and recognition memory tasks in East Asian than in Western participants (Gutchess et al., 2006; Unsworth & Pexman, 2005). An alternative suggestion (Saalbach & Imai, 2007) is that semantic relations are universally significant and modulate task performance in a similar fashion in representatives of Western and East Asian cultures. Experiments 3 and 4 examined whether semantic relations modulate associative recognition in Chinese participants at all and if the pattern resembles that shown by German participants.

In the following sections I summarize the major findings of the four experiments and then in separate sections discuss theoretical implications of these studies for research on the interaction between semantic and episodic memory, and for the cross-cultural research on memory. Next, I consider major limitations of the present investigations and outline questions that could be addressed in further work.

10.1 SUMMARY OF RESULTS

10.1.1 EXPERIMENT 1

In Experiment 1, participants encoded word pairs that contained either a categorical or thematic relation, or were unrelated by performing a single item mental imagery task. They then took a standard associative recognition memory test which required them to discriminate between old, rearranged, and new word pairs.

Behavioral results showed that categorically related pairs were recognized more accurately than thematically related ones, however, recognition of rearranged categorical pairs was accompanied by a higher proportion of false alarms than recognition of thematic pairs, suggesting that old/rearranged discrimination was especially difficult in this condition. ERP indices of successful familiarity- and recollection-based associative recognition were operationalized as contrasts between ERP waveforms elicited by correctly responded to old and new word pairs 350-550 and 550-750ms, respectively, after the onset of a word pair at test. Comparing these early and late old/new effects in the categorical and thematic conditions suggested comparable early frontal old/new effects in both conditions, whereas the late parietal old/new effect was observed in the categorical condition only.

The results of Experiment 1 support previous demonstrations that processes engaged in associative recognition are modulated by the type of pre-existing semantic relationship between the paired associates (Greve et al., 2007; Opitz & Cornell, 2006; Rhodes & Donaldson, 2007b). Novel evidence delivered by Experiment 1 suggests that recollection might be less critical for recognition of thematically related word pairs than it is for categorical associates. Importantly, attenuated involvement of recollection in the thematic condition was not a consequence of lower levels of recognition performance in this condition this pattern was replicated in post-hoc analyses when accuracy in the thematic and categorical conditions was equated. Moreover, differences in the modulation of recollection are unlikely to be attributed to a more favorable effect of mental imagery for the encoding of categorically related concepts: comparing ERPs elicited at encoding in the categorical and thematic conditions revealed that, the type of relation did not modulate the N400 (a component sensitive to differences in the semantic memory access and performance on imagery tasks) (Kutas & Federmeier, 2000, 2011; Nittono et al., 2002; West, 2000).

Analysis of old/new effects associated with recognition of unrelated pairs showed no evidence of the early frontal old/new effect, suggesting that its presence was restricted to the two semantically related conditions. This indicates that a pre-experimental semantic relationship between paired words supports familiarity-based associative recognition, and this holds even in cases when word pairs were not unitized into single compounds (for a review on unitization and its effect on associative recognition memory see Section 3.2). It is noteworthy, that the early frontal old/new effects found in both related conditions cannot be attributed to facilitated semantic processing typically reflected in the attenuation of the amplitude of the N400: comparing ERPs to new word pairs in the categorical, thematic and unrelated conditions provided no indication for modulation by relation condition on the frontal sites.

10.1.2 EXPERIMENT 2

Experiment 1 did not demonstrate any enhancement of the early frontal old/new effect in the thematic compared to categorical condition. It nonetheless indicated that familiarity might have played a more critical role in the thematic than in the categorical condition because the early frontal old/new effect was the only correlate of successful recognition in the thematic condition. Experiment 2 was designed to obtain further evidence for a more crucial role of familiarity in the recognition of thematically than categorically related pairs. I changed the testing procedure from a standard Y/N associative recognition (old vs. rearranged vs. new) to a forced-choice format in which participants had to select a word pair they actually studied from two alternatives (old, rearranged). Unlike Y/N recognition tests that encourage strong engagement of recollection, this type of test format allows participants to perform a task on the basis of recollection but also by choosing the word pair with the strongest familiarity signal (Clark et al., 1993; M. M. Patterson & Hertzog, 2010; Norman & O'Reilly, 2003). Following the recognition task, participants had to indicate the mnemonic process they relied on – remembering, knowing or guessing.

The critical finding of Experiment 2 was a higher proportion of Know-based responses associated with correctly recognized thematic pairs than correctly recognized categorical pairs indicating that familiarity contributed to associative recognition of this relation type more than it did in the categorical condition. Though overall there were differences in the proportion of R-responses between categorical and thematic conditions, two post-hoc analyses pointed in this direction whilst simultaneously confirming a higher reliance on familiarity in the thematic condition. In one of these analyses, I divided participants into two groups: one with higher recognition accuracy in the categorical than in the thematic condition ("categorical preference" group), and another with higher performance in the thematic condition ("thematic preference" group). Comparing R- and K-based hit-rates within the groups, suggested that better recognition performance in the categorical condition was associated with higher proportion of R-responding as compared to the thematic condition. Contrary to that, mnemonic benefit in the thematic relation as compared to the categorical was related to higher correct K-based recognition in this condition. Another analysis revealed a positive linear relationship between performance accuracy in the categorical condition and general reliance on recollection ate test. Conversely, recognition performance in the thematic condition positively correlated with familiarity-based recognition (correct K-responses). Along with indicating a critical role of familiarity in recognition of thematically related associates, both types of post-hoc analyses imply that recollection made a more critical contribution to associative recognition of categorically than thematically related associates.

10.1.3 EXPERIMENT 3

Experiments 3 was cross-culturally oriented and aimed at investigating whether semantic relational information modulates engagement of familiarity/recollection in associative recognition in East Asians and whether the pattern of modulation is similar to that shown by German participants. Chinese participants were recruited to take part in Experiment 3 that was procedurally analogous to Experiment 1 except that time to perform a mental imagery task was increased at encoding following pre-experimental piloting. Experiment 3 was conducted entirely in Mandarin Chinese.

In spite of a behavioral data pattern being highly similar to that of German participants, the major finding of Experiment 3 was an observation that the type of relation did not modulate ERP correlates of successful associative recognition in Chinese participants. Recognition of categorical, thematic and unrelated pairs was accompanied by late parietal old/new effects, only, implicating a crucial role of recollection in associative recognition irrespective of relation type. On their own, the electrophysiological results of Experiment 3 could be interpreted as an indication that semantic information does not guide the choice of associative recognition processes in Chinese participants. Whether this is the case will be discussed in Section 10.2.2.

10.1.4 EXPERIMENT 4

Continuing the cross-cultural line of research, Experiment 4 aimed at gaining further insights into the modulation of associative recognition processes by the type of semantic relation in Chinese participants. Because associative recognition tasks of Y/N format (requiring old/ rearranged/ new discrimination) set rather strong demands on recruitment of recollection, following the logic described in the rationale for Experiment 2, I tried to loosen this requirement to provide more options for solving the recognition task on the basis of familiarity by employing a forced-choice format. Experiment 4, therefore, closely resembled Experiment 2 with some adjustments to the timing procedure (slightly prolonged exposure to stimuli at encoding and retrieval following pre-experimental piloting).

Experiment 4 revealed that in this kind of task associative recognition was modulated by semantic relation. Recollection turned out to be the main process affected: the highest R-response rate was observed in the categorical condition, slightly lower in the thematic, and the lowest in the unrelated condition. Familiarity was also modulated in that proportion of correct K responses associated with recognition of unrelated pairs was lower than in both of the related conditions. No indication of familiaritys differential contribution to recognition of categorical/thematic pairs was observed. The findings of Experiment 4 show that under certain experimental conditions (FC test format) the type of semantic relatedness modulates processes engaged in associative recognition in Chinese participants with primary modulation concerning reliance on recollection.

10.2 THEORETICAL IMPLICATIONS

In what follows, I shall first discuss theoretical implications of Experiments 1 and 2 that concern differential modulation of associative recognition memory by categorical and thematic relations. Then, inferences following from Experiments 1, 2 and 3, 4 are discussed from a cross-cultural perspective[1].

10.2.1 MODULATION OF ASSOCIATIVE RECOGNITION MEMORY BY DIFFERENT TYPES OF SEMANTIC RELATIONAL INFORMATION

Experiments 1 and 2 (as well as Experiment 4) provide a demonstration for the effect of semantic structure on associative recognition memory. Experiment 1 replicated the results of the ERP studies demonstrating that semantic relatedness between to-be-learned associates supports familiarity-based associative recognition (Greve et al., 2007; Opitz & Cornell, 2006) whereas arbitrary associates are recognized on the basis of recollection alone (D. I. Donaldson & Rugg, 1998, 1999). Prior behavioral studies demonstrating a beneficial effect of semantic relatedness on associative recognition memory (Naveh-Benjamin, 2000; Naveh-Benjamin et al., 2003, 2005; Badham et al., in press; M. M. Patterson et al., 2009) attributed it to the role of pre-established connections between the related concepts. Long-standing relational links are easily activated and strengthened when a related word pair is encountered at study, whilst a single exposure during the encoding allows to establish only a few connections between arbitrarily paired concepts (MacKay, 1990; Badham et al., in press; M. M. Patterson et al., 2009). In turn, retrieving these weak newly established connections could necessitate a strong involvement of hippocampally-driven recollection (see Section 1.2.2 for a review on how hippocampus supports learning and retrieval of novel associations), whist familiarity signal can be generated in response to related pairs at test.

Different types of semantic relations appear to affect associative recognition in their own ways. Experiments 1 and 2 provide first reports of differential contribution of familiarity and recollection to associative recognition of categorically and thematically related associates. Below I propose a way to account for the modulation of associative recognition memory processes from the perspective of differences in the nature of underlying semantic representations.

[1]Note that inferences about the impact of different types of semantic relations on associative recognition with regard to underlying semantic representations are made primarily on the basis of German data. This relates to the fact that prior research in this direction was conducted with Western participants (e.g., English, German). Due to the lack of relevant research with East Asian participants, the data from Chinese participants is discussed mostly from the cross-cultural comparative perspective.

10.2.1.1 ASSOCIATIVE RECOGNITION OF THEMATICALLY RELATED PAIRS

Previous research has investigated the effect of pre-experimental semantic relatedness on episodic recognition memory by primarily employing the contrast between categorically-related and unrelated word pairs (Greve et al., 2007; Naveh-Benjamin et al., 2005; M. M. Patterson et al., 2009). Whereas Opitz and Cornell (2006) demonstrated that encoding items by integrating them into a common theme boosted subsequent familiarity-based item recognition (Section 3.3), no one has explicitly examined how preexisting thematic relations impact upon associative memory processes. This was accomplished in Experiments 1 and 2. Though these experiments used different paradigms and measurement methods to assess contributions of familiarity and recollection, the data from two experiments complement each other in demonstrating a critical role of familiarity and an attenuated contribution of recollection to associative recognition of thematic relations. Observing the early frontal old/new effect in the absence of the late parietal effect in the thematic condition in Experiment 1 indicated that familiarity might provide sufficient support for associative recognition of thematically related pairs. Complementary to that, Experiment 2 showed that associative recognition was accompanied by a higher proportion of know-responses in the thematic than in the categorical condition and revealed a positive linear relationship between familiarity-based recognition and performance accuracy in this condition. Moreover, mnemonic advantage of participants with superior recognition performance in the thematic than in the categorical condition was associated with higher levels of K-based responding in the this condition compared to the categorical.

An important observation delivered by Experiment 1 is the absence of a late parietal old/new effect. Arguably, this implies that compared to associative recognition of categorical and unrelated pairings, the contribution of recollection might be less critical for successfully performing associative recognition task with stimuli of this type. Experiment 2 likewise delivered an indirect support for this inference. Though failing to uncover differences in the proportion of remember-responses between categorical and thematic conditions, Experiment 2 showed that recognition accuracy in the categorical condition correlated with reliance on recollection at test, whereas no such correlation was found in the thematic condition.

Overall, the pattern of results observed in the thematic condition has some correspondence with a pattern obtained in associative recognition memory studies that use unitized item combinations, such as existing compounds, e.g., *traffic – jam* (Rhodes & Donaldson, 2007b; Ford et al., 2010) or novel compounds experimentally established in new definitions, e.g. *smoke – apple* (Bader et al., 2010; Quamme et al., 2007). The peculiarity of such stimuli is that they can be thought of as forming joint or unitized representations (see Section 3.2 for a review on unitization). Akin to representations of single entities, the retrieval of joint inflexible representations as a whole can be supported by perirhinal cortex on the basis of familiarity and can be accompanied by an attenuated engagement of hippocampally-driven recollection possibly due to the lack of need for the retrieval of flexible relational connections (see Section 3.2 for a review on functional roles of different MTL structures in recognition memory Eichenbaum et al., 2007; Diana et al., 2007;

Ranganath, 2010; Norman & O'Reilly, 2003; Henke, 2010). Not only compounds were employed as examples of unitized representations. Some researchers treated item and its color (Diana et al., 2008), configurations of facial parts (Yonelinas et al., 1999), pairs of morphed phases of the same person (Jäger et al., 2006) as forming this kind of representations. While in the narrow sense, a unitized representation emerges only when individual constituents are "blended together into an inseparable [] representation and cannot be reactivated individually" (Henke, 2010, p. 523), in the broad sense a set of associated items could also make up a unitized representation (Yonelinas et al., 2010).

Given the latter broad understanding of what makes several items unitized, thematically related concepts can be thought of as forming representations in some way analogous to unitized representations. One such characteristics of thematic relations that makes them akin to unitized representations is the capacity to be integrated into a thematic scenario. As described in Section 3.4.2, concepts become thematically related when they co-occur in a situation in which they play complementary roles (Gentner & Brem, 1999; Estes et al., 2011; Lin & Murphy, 2001). As Gentner and Brem (1999, p.179) put it, it is experience that "tells people that snow and shovel interact". In the pre-experimental rating of stimulus materials in the present thesis, I asked participants to identify the type of relation between paired concepts. Thematic relation was defined as a non-categorical relation emerging between concepts when they, e.g., tend to co-occur in the same situation. There was a high agreement between participants that thematic word pairs indeed shared this kind of relation, indicating that concepts related in this way were indeed perceived as appearing in some joint scenario. Wisniewski and Bassok (1999) conducted a study in which they asked participants to rate the similarity of two concepts (categorically and thematically related; categorically related only; thematically related only; unrelated) and provide a justification for their rating. Independent annotators then classified the similarity explanations as either based on feature comparison (*ship – canoe* are "similar because they are both used to travel on water", p. 218) or integration into a particular scenario (*car – mechanic* were considered "somewhat similar because mechanic works on cars", p. 218). The results indicated that, unlike categorical relatedness, the presence of a thematic relationship between concepts yielded similarity ratings that were heavily based on integration into a scene, leading the authors to conclude that thematic relations are congruent with integrative processing. Estes and Jones (2009) reported the results of a priming experiment in which they observed facilitated processing of a target whenever it was possible to assign it a plausible functional role in a theme defined by a prime, even when prime – target combinations were not strongly associated, such as in *beach – house* (see also Jones and Estes (to appear)). These findings provide a demonstration that such concepts due to their capacity to complement each other in a theme are rapidly integrated into coherent and easily processed meaningful structures (Estes & Jones, 2009).

Another aspect that could contribute to effortless integration of thematically related pairs into a joint representation is a high associative strength between the concepts (Estes et al., 2011; Lin & Murphy, 2001). Repeated experience with a particular item combination establishes a strong associative connection between the constituents, such that in effect thinking about one concept automatically activates another partner concept. In this thesis, I employed conventional, i.e. well-established and salient, thematic relations which arise as a result of a repeated co-occurrence of items in prototypical situational contexts and are strongly associated (confirmed by the pre-experimental ratings). Hence, thematically related words here, e.g., *actor – stage*, could have been processed as strongly connected holistic representations. Neuroimaging investigation by Amso, Davidson, Johnson, Glover, and Casey (2005) showed that with repeated exposure, item combinations stop being treated as constituting separate representations and get integrated to the extent that they bypass hippocampal processing, that is processing by a brain structure implicated in associative learning and binding individual elements of a study episode (see Section 1.2.2 for a review, but also Eichenbaum et al., 2007; Diana et al., 2007; Staresina & Davachi, 2008; Ranganath, 2010). Research on visual object recognition likewise suggests that information about typically co-occurring objects, interrelations between them, and prototypical contexts might be stored as joint contextual frames (Bar, 2004) and that contextual frames are automatically activated even by individual objects (Aminoff, Gronau, & Bar, 2007; Bar & Aminoff, 2003; Bar, Aminoff, & Schacter, 2008).

Inference following from this suggests that presence of a conventional thematic relation between paired concepts could allow for a rapid integration of these concepts into holistic representations which retrieval then does not require active engagement of hipocampally-driven recollection because these items are represented in terms of a unifying theme/frame (e.g., frame "play" for a thematic pair *actor – stage*) and by this can be recognized on the basis of familiarity alone. Results of the present experiments extend this proposal of Opitz and Cornell (2006) to the domain of associative recognition memory by demonstrating that recognition of thematically related pairs can be efficiently supported by familiarity and, moreover, accompanied by an attenuated contribution of recollection.

An alternative possibility is that participants built compounds when encoding thematic word pairs. Previous research (Estes & Jones, 2009; Badham et al., in press) showed that unrelated words that have a potential be linked together to produce a coherent compound, e.g. *horse – doctor*, *town – church*, get automatically joint into compounds even if participants are not instructed to do so. This could have likely happened in the present experiments, too, given the highest capacity of thematic pairs to form compounds as demonstrated by the pre-experimental ratings. Though item imagery tasks were employed in all of the experiments to prevent such strategic compound formation, it cannot be entirely excluded that the pattern of results in the thematic condition was in part been driven by a higher unitizability of thematic pairs into compounds. To control for the effect of compound-formation, further experiments might attempt to employ a stimulus set that equates categorical and thematic associates on this dimension.

10.2.1.2 ASSOCIATIVE RECOGNITION OF CATEGORICALLY RELATED PAIRS

The pattern of results for the categorically-related pairs in Experiment 1 demonstrates the presence of reliable early frontal and late parietal old/new effects. Importantly, these effects are topographically dissociable from one another implying contribution from different underlying neural processes – familiarity and recollection – to associative recognition of this relation type. Extending the results of Experiment 1, Experiment 2 pointed to an important role of recollection in associative recognition of categorical associates: there was a positive linear relationship between recognition accuracy in this condition and general reliance on recollection at test. Additionally, the group of participants with a superior performance in the categorical than thematic condition, achieved this advantage by relying more on recollection in the categorical than in the thematic condition. The results of Experiment 4 with Chinese participants also revealed that a higher rate of R-responding was associated with correct recognition of the categorical pairings compared to the thematic and unrelated conditions.

These results are in line with ERP findings reported by Greve et al. (2007); Rhodes and Donaldson (2008) who observed that both familiarity and recollection were engaged in associative recognition of categorically related pairs. The same conclusion follows from a behavioral study by M. M. Patterson et al. (2009) who investigated associative recognition of categorically related and unrelated word pairs in younger and older adults. Assuming that familiarity-based recognition occurs faster than recollection (Yonelinas, 2002; Rugg & Yonelinas, 2003; Rugg & Curran, 2007), they used a response-deadline procedure to tap into the involvement of recollection and familiarity in associative recognition. They found that both younger and older adults benefited from categorical relatedness at a short deadline – a finding indicating that familiarity could support recognition decision in this condition compared to the unrelated. Moreover, when a longer response deadline was used, older adults performance reaching the level comparable to younger adult – a finding indicating that recollection, too, was affected by the categorical relatedness of items.

Along with complementing the results of these studies, the present experiments also hint for a critical contribution of recollection in the categorical condition. It is interesting why categorically related word pairs, in contrast to thematic, seem to engage familiarity but also require a considerable contribution of recollection for efficient recognition. A hint for a potential explanation comes from the behavioral results of Experiments 1 (and Exp. 3) indicating a higher false alarm rate in the rearranged categorical than thematic condition. Higher proportion of false alarms in the categorical condition compared to the unrelated one was also observed in prior research (Greve et al., 2007; M. M. Patterson et al., 2009; Rhodes & Donaldson, 2007b), and which all together suggests that the presence of categorical relatedness between items may influence associative recognition judgments in that it is especially difficult to reject recombined pairs as previously unstudied when they entail a categorical membership.

False alarms are thought to reflect a situation in which unstudied lures feel so familiar that a participant is unable to differentiate them from studied items (Schacter & Dodson, 2001). Similarity between old and lure items seems to break down the capacity of familiarity to discriminate between them while recollection might still be capable of the discrimination (Curran, 2000; Mecklinger, 2000; Nessler, Mecklinger, & Penney, 2001; Yonelinas, 2002). Familiarity is conceptualized as a global matching process: its strength increases the closer the test item (cue) matches the memory trace (Yonelinas, 2002, see Section 1.1). When representations of studied and unstudied items strongly overlap, familiarity strength also increases for lures making it impossible to distinguish between the two types of items on the basis of this signal alone. In contrast to familiarity, recollection is thought of as a threshold process: recognition of stimuli for which the recollective threshold is exceeded is accompanied by the recovery of the specific details of the study episode (Yonelinas, 2002; Yonelinas et al., 2010; Diana et al., 2006). Thus when the test procedure requires discriminating between highly similar old and lure items, recollection might support this process by delivering the specific information about the prior occurrence, that is participants need to recollect the studied pair in order to reject the rearranged probe (Curran, 2000; M. M. Patterson et al., 2009).

This explanation based on the types of processes underlying familiarity and recollection is compatible with the neurocomputational CLS model of Norman and O'Reilly (2003) described in Section 1.2.1 (see also Norman & O'Reilly, 2003; Norman, 2010). Perirhinal cortex, associated with familiarity-based recognition (Giovanello et al., 2006; Eichenbaum et al., 2007; Diana et al., 2008; Knowlton & Eldridge, 2006), assigns overlapping representations to similar items, thereby yielding highly similar activation patterns for studied and unstudied lures failing to discriminate between them. In contrast, although lures can trigger recall due to their high similarity to studied patterns, hippocampus, due to its ability to assign separate distinct representations to items, can still reject them "on the basis of mismatch of retrieved information and the recalled cue" (Norman & O'Reilly, 2003, p. 614), i.e., on the basis of a recall-to-reject strategy.

These theoretical assumptions were confirmed by a number of studies (Curran, 2000; Nessler et al., 2001). An ERP study by Nessler et al. (2001) showed that correct recognition of old items and false recognition of related lures lead to comparable early frontal old/new effects, implying equally large familiarity signals in both cases. In contrast, a significantly larger late parietal old/new effect was observed for correctly classified old items than for falsely recognized lures suggesting higher sensitivity of recollection to old vs. related lure distinction. Dosher and Rosedale (1991) could show that false recognition is more likely to happen on the basis of familiarity in a behavioural associative recognition memory study. They manipulated semantic relatedness between paired concepts in associative recognition tests with short and long response deadlines. They observed that semantic relatedness (categorical relatedness, synonyms and antonyms) intruded into episodic memory judgments only under a short response deadline: in this response condition, participants false alarmed to semantically related but previously unstudied word pairs more frequently than under the long response deadline. The results of the study demonstrated that false recognition occurred under the condition when participants had no time to recruit slowly acting recollection and responded on the basis of familiarity.

As explained in Section 7.4.1, associative recognition is similar to the related lure testing paradigm as in this case studied word pairs A-B/C-D and a rearranged pair A-D have overlapping representations (Norman & O'Reilly, 2003). The overlap is stronger in case when word pairs are semantically related than arbitrarily paired because pre-experimentally related pairs already share a set of common features and this is especially the case with categorical associates which are particularly vulnerable to the effects of lure-similarity on recognition memory (Roediger & McDermott, 1995;

Schacter & Dodson, 2001; Park, Shobe, & Kihlstrom, 2005). As theorized by Markman and Wisniewski (1997) and likewise confirmed by various existing rating studies (Estes et al., 2011; Lin & Murphy, 2001; Murphy, 2001), including the pre-experimental ratings for the stimuli employed here, categorical relation is characterized by a high degree of feature overlap between the related concepts of the same ontological level. Thereby, each set of three items used for the construction of old and rearranged categorical pairs in the present experiment shared a considerable amount of common features, e.g. consider *dancer – singer – actor*, in turn leading to a large feature overlap between the studied and rearranged categorical pairs, *actor – singer* vs. *dancer – singer* (for a schematic representation see Figure 10.2.1.2). When encountering a rearranged pair at test, a high familiarity signal is elicited because many features characterizing a pair dancer-singer (e.g., are humans, are performers, can be famous, etc.) were already activated and by this strengthened at study. In this case, familiarity alone might not be sufficient for performing associative recognition of the categorical pairings yielding a high proportion of false alarms in case of pure familiarity-based responding. In contrast, when the studied pattern is recollected, it can be compared to the cue-pattern and a rearranged pair can then be successfully rejected.

Though a similar argument could be applied to thematically related pairs, it appears to me that such word pairs should be less affected by false recognition due a lesser number of shared features (Estes et al., in press; pre-experimental ratings of the present thesis) and to a uniqueness of thematic links between paired concepts. As described above, thematic relation typically emerges between concepts that play complementary roles in a thematic scenario meaning that they come from different common categories and do not share many similar features (Lin & Murphy, 2001). Instead, they are connected via situationally-formed thematic links, which could be rather unique for every particular concept combination. For instance, thematic associates *actor – stage* might activate a slightly different associative chain (e.g., play, theater, darker light, monologues, etc.) compared to *dancer – stage* (ballet, ballerinas in costumes, changing lights, music). This in turn means that old target pairs and related lure pairs in this condition are more distinct from each other than those related categorically. Distinctiveness appears to be an important parameter affecting false recognition. Schacter and Dodson (2001) proposed that false recognition of semantically similar items is driven by gist memory, i.e., memory for similar semantic features in the absence of memory for specific details. For example, focusing on specific details about the studied concepts at encoding reduces FA rate to related lures at test (Schacter, Israel, & Racine, 1999; Israel & Schacter, 1997). By this, it is possible that successfully encoding this, a unique link between thematic associates can subsequently lead to true familiarity-based recognition and reduced levels of false recognition. Future research in this direction could address the question of the nature of the familiarity signals elicited by both types of relations.

10.2.2 CROSS-CULTURAL DIFFERENCES IN MNEMONIC PROCESSES ENGAGED IN ASSOCIATIVE RECOGNITION

According to cross-cultural research, there might be differences in how information about semantic relationships affects performance in different tasks in Western and East Asian participants

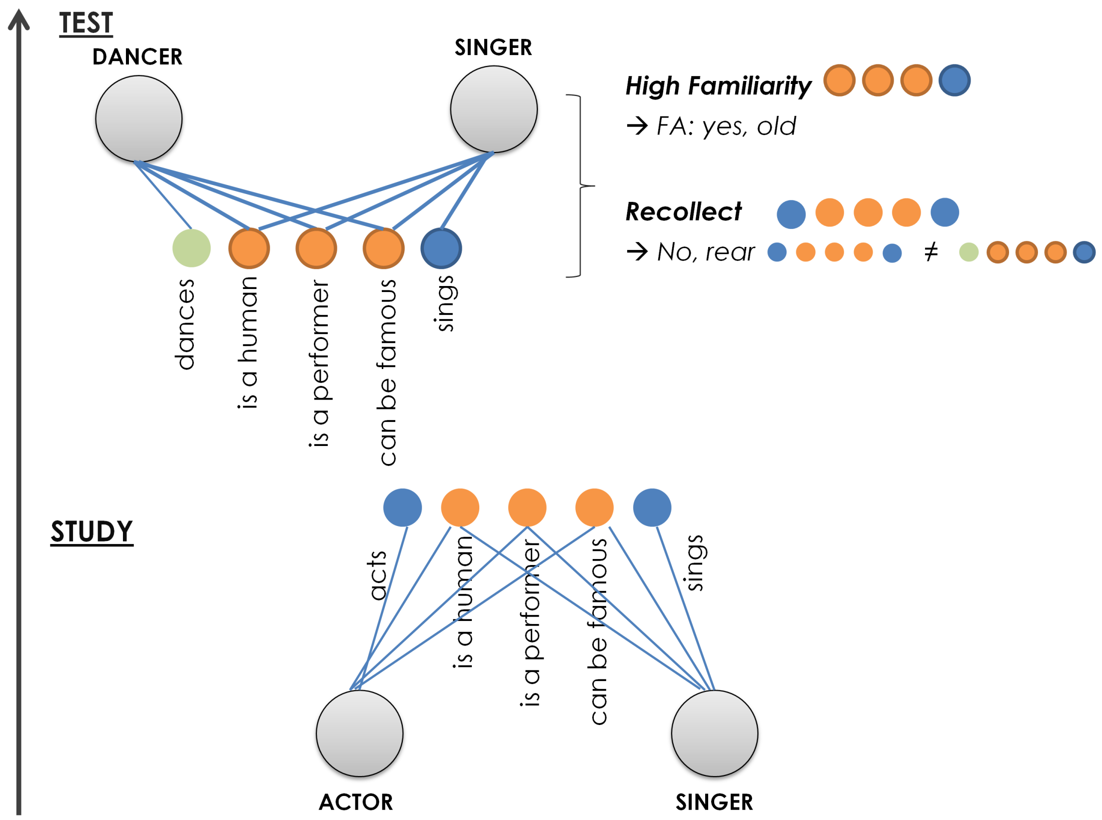


Figure 10.1: Schematic representation of old vs. rearranged discrimination of categorically related pairs. The lower panel shows activation of common (orange) and distinct (blue) features by a word pair *actor – singer* during the study phase. Encountering a rearranged pair *dancer – singer* at test (upper panel) activates an overlapping set of features (orange and blue). Because these features were already accessed during the study, activation of these features at test is rather strong (represented as thicker lines). If relying only on this strong familiarity signal when making a recognition decision, a participant can erroneously endorse the rearranged pair as old. Instead, if using the test pattern to trigger recollection of the complete studied pattern, a participant can then compare the retrieved pattern with the cue pattern and accurately classify the test pair as rearranged.

(Chiu, 1972; Ji et al., 2004; Gutchess et al., 2006; Unsworth & Pexman, 2005). Experiments 3 and 4 report novel findings regarding the impact of categorical and thematic relations on associative recognition memory in Chinese participants.

Experiment 3 did not provide any evidence for differential modulation of electrophysiological signatures of familiarity and recollection by different types of relational information. Correct responses to word pairs in the categorical, thematic and unrelated conditions elicited only a late parietal old/new effect suggesting engagement of recollection irrespective of the type of semantic relation. On the first sight, this result complements the findings of Gutchess et al. (2006) and Unsworth and Pexman (2005) who likewise observed no effect of the type of semantic relation in free recall, forced-choice categorization and priming tasks in East Asian participants, whereas the effect was pronounced in Western participants (for a review of these experiments see Section 4).

Yet, concluding that the type of semantic relation has no impact on associative recognition in Chinese participants seems premature. Whereas no effect was observed on the electrophysiological correlates of mnemonic processes, behavioural results in Experiment 3 were modulated by the type of relation. Just like German participants, Chinese were more accurate in correctly responding to old and new word pairs in the categorical than in the thematic condition, whilst simultaneously experiencing more difficulties in correctly identifying rearranged word pairs in this condition. This speaks to the point addressed in the previous section that the presence of a categorical relationship between paired concepts promotes false recognition. Moreover, Experiment 4 provided a demonstration that successful old vs. rearranged discrimination was associated with a higher engagement of recollection in the categorical than thematic condition – a mechanism allowing to overcome false memories in a more efficient way than familiarity. Apart from that, Experiment 4 showed that semantically related paired concepts attracted more K-based judgments than arbitrary combinations which is an indication that familiarity could support associative recognition of related pairs in Chinese participants. Complementing the proposal of Saalbach and Imai (2007) on the overall cultural universality of effects of categorical/thematic structures on performance in various tasks, these findings tentatively support the idea that there are similarities in the way categorical and thematic structures affect associative recognition in German and Chinese participants.

In general, primary cross-cultural differences revealed in the present thesis seem to relate not to the way semantic information guides engagement of familiarity/recollection in associative recognition, but to the basic functioning of associative recognition processes as such. As can be inferred from the presence of robust late parietal old/new effects in Experiment 3 and by the primary impact of semantic structure on the proportion of R-responses in Experiment 4, recollection was the major process in associative recognition in Chinese participants and semantic relatedness in the first turn modulated this "default" process. Familiarity seems to support recognition of related pairs as compared to unrelated ones but only under certain circumstances (FC format in Experiment 4). In contrast, a more flexible engagement of familiarity and recollection, which contribution was determined by the type of semantic relation, accompanied associative recognition in German participants as suggested by Experiments 1 and 3. It therefore appears that whilst for German participants, semantic information strongly guides which process is actively engaged in associative recognition, Chinese participants rely on a "default" recollection process with relational information then primarily modulating the relative contribution of recollection.

As discussed in Chapter 1, recollection is thought to yield retrieval of details of the study episode, item-context and item-item bindings (Yonelinas, 2002; Woodruff et al., 2006; Rugg & Yonelinas, 2003; Rugg & Curran, 2007). Assuming that recollection functions as a "default" mode in associative recognition tasks in Chinese participants implies that they actively attempted to access some relational information associated with previous occurrence of a test word pair (it could be information about the type of relation between paired elements, but also memories about mental images constructed, imagery ratings, temporal position of the word pair in a study list, etc.). The proposal that East Asians might generally focus more actively on relational information than Westerners during encoding and retrieval from memory was advanced in several studies from the domain of visual cognition (Masuda & Nisbett, 2001; Chua, Boland, & Nisbett, 2005; Gutchess & Indeck, 2009; Nisbett & Miyamoto, 2005; Miyamoto & Wilken, in press)[2]. For instance, in an experiment by Chua et al. (2005), participants studied pictures of focal objects on a complex background and discriminated between new and old objects during the subsequent item recognition test. Old objects were either presented on the same background as at study or on a different one. Monitoring eye-movements during the study phase revealed that Chinese participants gazed more to the background and less to focal objects than American participants. At test, Chua et al. observed that when old objects were presented on novel backgrounds, object recognition accuracy declined for Chinese participants whereas it was not affected for American participants. These results suggest that Asian participants engaged more readily in binding object-context information at encoding and at test suffered more from the disruption of relational information, that is when the background was changed (for results and inferences, see Masuda & Nisbett, 2001).

Mnemonic differences in binding pieces of information are thought to relate to Asians and Westerners differentially directing their attention to focal objects vs. contextual field (Kitayama, Duffy, Kawamura, & Larsen, 2003; Masuda & Nisbett, 2001, 2006; Chua et al., 2005; Miyamoto, Nisbett, & Masuda, 2006). Studies that used a *change detection paradigm*, in which participants sequentially see two similar episodes/pictures and then have to report the differences between them, demonstrated that East Asian participants are better in identifying changes in the contextual information in a sequence of two animated vignettes than American participants (Masuda & Nisbett, 2006; Miyamoto et al., 2006). A recent fMRI experiment by Hedden, Ketay, Aron, Markus, and Gabrieli (2008) employed a visuospatial task that either required East Asian/American participants to attend to context or ignore it attending only to the focal object. Greater activations were found in the fronto-parietal attentional control network when participants had to perform a culturally dispreferred type of task (East Asians – attending to focal object only; Americans – attending to object and context) than culturally congruent one suggesting that engaging in culturally atypical tasks required additional control processes. Miyamoto et al. (2006) proposed that a bias to attend to either focal objects or to the contextual field might be attributed to cultural/environmental affordances. They conducted a rating study which showed that typical East Asian (Japanese) outdoor scenes are rated as more complex and containing more elements than corresponding American scenes. Moreover, they demonstrated that shortly exposing both Japanese and American participants with Japanese scenes leads to detecting more changes in the contextual background in a change-dtection task with culturally neutral animated vignettes. The results were interpreted as suggesting that the densely-packed East Asian environment fosters to direct attention more to interrelations between objects and the surrounding context, whilst simple Western environment encourages attending to salient objects and their features.

Whereas behavioral experiments consistently find evidence for more effective object-context binding in East Asians than in Westerners, neuroimaging research has so far provided little support for differences in the underlying neural mechanisms (Goh et al., 2007; Gutchess et al., 2006). Gutchess et al. (2006) failed to find convincing evidence for differences in the background-

[2]Research on visual cognition is referred to here because, to the best of my knowledge, no work in this direction was conducted with verbal materials.

processing regions (e.g., hippocampus and parahippocampal gyrus) during encoding of visual scenes (though finding such differences in object-processing areas). The results of Experiments 3 and 4 of the present thesis point to a high reliance on engagement of recollection – mnemonic process responsible for retrieving bindings and relations between individual elements – disregarding the type of relation between concepts in Chinese participants. This, therefore, suggests there might be indeed cross-cultural differences in the way information gets bound at encoding and retrieved at test implicating that investigating cross-cultural differences in binding mechanisms might be a promising direction. It should be noted that unlike the above reviewed studies, the present experiments do not originate from the domain of visual cognition. This points to a challenge in constructing a comprehensive picture of cross-cultural differences/similarities in cognitive processes as experiment outcomes vary considerably with tasks and stimuli employed.

To sum up, Experiments 3 and 4 suggest that a) semantic information guides associative recognition processes in Chinese participants which is reflected on a level of behavioral markers, and b) in some ways this modulation is consistent with that shown by German participants (e.g., higher false recognition of categorically than thematically related pairs and higher involvement of recollection in this condition), and c) recollection seems to function as a "default" process in associative recognition in Chinese participants.

10.3 LIMITATIONS OF THE PRESENT EXPERIMENTS AND FURTHER WORK

The present thesis delivered first evidence for how long-standing categorical and thematic relations modulate engagement of familiarity and recollection in associative recognition memory and proposed to account for these results in terms of differences in the semantic representations underlying these relations. The effects of semantic relatedness on associative recognition were compared across cultures (German vs. Chinese participants) pointing to primary differences in the basic functioning of associative recognition memory rather than in the way its processes are guided by semantic structures.

It is important to acknowledge several major caveats associated with the data. The first caveat concerns the operational definition of associative recognition memory in the ERP experiments. Whilst the behavioral experiments 2 and 4 focused on old-rearranged discrimination, associative recognition in ERP studies was operationalized as a contrast between waveforms elicited by correctly responded to old and new word pairs. Whereas the old/new contrast is widely used in associative recognition memory research (Bader et al., 2010; Wiegand et al., 2011; Greve et al., 2007; Rhodes & Donaldson, 2007b), it might reflect not only effects of associative recognition memory but also of recognition memory for single items. Some researchers argue that old/rearranged discrimination should provide a purer measure of associative recognition memory as in this case the contrasted conditions are equated for item familiarity effects due to all words being previously encountered. Though there is little doubt about the necessity of the inclusion of rearranged pairs into tests of associative recognition which guarantees that successful discrimination between old and rearranged pairs is solely attributed to recognition of associative links (Hockley & Consoli, 1999), several problems are associated with a functional interpretation of ERP responses to correctly classified rearranged pairs. It could be that participants strategically accept word pairs that feel familiar as "rearranged" and only endorse "old" those word pairs for which they recollect specific details (D. I. Donaldson & Rugg, 1998). If this strategy is adopted, then differences in associative familiarity are unlikely to be revealed by an old-rearranged contrast. Moreover, rearranged pairs are constructed such that both members of a previously studied pair reappear at test but in different combinations. This means, that when a participant encounters a recombined pair, she has an option to endorse a pair as rearranged by recollecting the study episode or by recognizing that the partner word was previously encountered during the test in a different combination (Bader et al., 2010). Even though these arguments speak against contrasting old-rearranged responses in the ERP analyses, it should be kept in mind that old/new contrasts in the present experiments might be in part contaminated by item recognition memory effects.

Another limitation concerns the comparison of the German and Chinese data. Following a pilot study, the timings of experimental procedures in Experiments 3 and 4 had to be adjusted in order to achieve above chance levels of performance in Chinese participants. Though increasing encoding at about 1 second is unlikely to significantly change episodic recognition processes (see Section 8.4), comparison of the results of experiments 1, 2 and 3, 4 should be made cautiously.

Therefore, findings of the present thesis require additional validation via replication. Furthermore, inferences derived from the present data should also be investigated. For example, further research could specifically address the question of whether familiarity accompanying recognition of the categorical relations in Experiment 1 and other ERP experiments (Greve et al., 2007; Rhodes & Donaldson, 2008) is indeed a consequence of high feature similarity of old and rearranged categorical items and is on its own not sufficient for successful associative recognition. As ERPs did not provide evidence for differential early frontal old/new effects in the categorical and thematic conditions and only the behavioural RK experiment (Exp. 2) allowed to observe such differences, it is advisable to conduct an experiment that would provide electrophysiological evidence for this differential modulations (e.g., introducing a speeded condition to endorse familiarity-based recognition). It also merits to further explore the proposal that Chinese participants use general reliance on recollection as a "default" processes in associative recognition, whereas the kind of process engaged for German participants might be guided by the type of semantic relation information. The proposal advanced in the present work that differential modulation of associative recognition memory by categorical and thematic associates can be attributed to differences in the nature of categorical and thematic relations (feature overlap in the categorical condition vs. holistic nature of thematic associates) could further be investigated by endorsing stimulus-compatible processing at encoding such as feature orientation/thematic integration. Such stimulus compatible processing might be expected to boost the asymmetries in the involvement of recognition processes.

10.4 CONCLUDING REMARKS

Taken together, the findings reported in this thesis further extend the evidence that semantic memory interacts with episodic memory (Opitz & Cornell, 2006; Greve et al., 2007) in that associative recognition differentially engages mnemonic mechanisms depending on the type of pre-existing semantic relation in a word pair. Associative recognition of categorically related word pairs seems to necessitate active engagement of recollection, whereas its contribution is attenuated when paired concepts can be integrated into thematic representations. The results also suggest that familiarity on its own might provide an efficient mechanism for associative recognition of pairings of the latter type.

From the cross-cultural perspective, the present findings provided preliminary indications that the type of semantic relation modulates associative recognition in Chinese participants in part in a similar fashion as in German participants. However, modulation by relation primarily impacts upon recollection suggesting whereas in Germans both processes – familiarity and recollection – are affected. Overall, it appears that Chinese participants rely on recollection as a "default" processes in associative recognition memory.

APPENDIX A

Questionnaire used in the pre-experimental rating of materials

Transcript of questionnaire instructions used in the pre-experimental rating of materials in Germany (original version was in German). Note that every participant had to evaluate each word pair on three parameters: type of relation; unitizability; semantic relatedness or strength of association (depending on version 1 or 2 of the questionnaire).

In the following questionnaire you will see a number of word pairs. Please, assess the following aspects of the relation between the words in a pair:

- Type of relation;
- How well can the two words be bound to form a single concept;
- Semantic relatedness // Strength of association

Here are some definitions which might help you to answer the questions:

Categorical relation exists between those words that can be classified as belonging to the same conceptual category (group).

Example: *City – Village* (Category: settlement)

Thematic relation exists between the words that do not belong to any common conceptual category but are related to each other in some other way (e.g., there is a causal relation between them or they tend to co-occur in the same situation or event, etc.).

Example: *City – Resident* (In every city there are residents)

No relation can be found between the words that neither belong to the same conceptual category nor normally tend to co-occur in the same situation.

Example: *City – Detergent*

When the second word can be attached to the first word leading to a formation of a new meaning, then the two words can be well **bound into a single concept**.

Example: *City – Planning* (new concept: city-planning)

Concepts that have similar properties are considered to **share common semantic features**.

Example: *Village – Town*

(These two concepts share many common semantic features: e.g., both of them have small population, occupy a relatively small geographical area, usually have a local municipality, etc.)

OR **in cases when a participant had a version of the questionnaire asking to evaluate associative strength**:

If upon reading the first word, the second word comes to your mind, then these words are **associated**.

Example: *City – Noise*

Now, to your task:

For each word pair that you will see, there are three incomplete statements regarding the relation between the words in a pair. Your task is to complete all the statements. Please, choose only one option that in your opinion completes the statement best.

Example:

Hockey – Football

1. Between the two words, there is ... relation:

categorical thematic no

2. The two words can be ... bound into a single concept:

very well well hardly not at all

3. The two words share ... common semantic features:

a lot of quite many few no

OR:

3. The two words are ... associated with each other:

very well well hardly not at all

APPENDIX B

A list of stimuli in German and Chinese

SET	QUADR.	MAIN WORD 1		MAIN WORD 2		TAXONOMIC		THEMATIC		UNRELATED		UNRELATED	
1	1	Ring	戒指	Armband	手镯	Kette	项链	Geschenk	礼物	Wiese	草地	Sonne	太阳
	2	Wüste	沙漠	Prärie	草原	Wiese	草地	Sonne	太阳	Kette	项链	Geschenk	礼物
2	1	Fluss	河流	Meer	大海	Ozean	大洋	Boot	船只	Schreibblock	便笺	Schreibtisch	书桌
	2	Tagebuch	日记	Notizheft	记事本	Schreibblock	便笺	Schreibtisch	书桌	Ozean	大洋	Boot	船只
3	1	Hagel	冰雹	Regen	雨	Schnee	白雪	Himmel	天空	Verkäufer	店员	Formular	表格
	2	Beamter	公务员	Buchhalter	会计	Verkäufer	店员	Formular	表格	Schnee	白雪	Himmel	天空
4	1	Stein	石头	Lehm	粘土	Sand	沙子	Baustelle	工地	Cello	大提琴	Orchester	乐队
	2	Saxophon	萨克斯风	Gitarre	吉他	Cello	大提琴	Orchester	乐队	Sand	沙子	Baustelle	工地
5	1	Hocker	凳子	Sitzbank	板凳	Stuhl	椅子	Holz	木头	Schwein	猪	Stall	牲口棚
	2	Schaf	绵羊	Ziege	山羊	Schwein	猪	Stall	牲口棚	Stuhl	椅子	Holz	木头
6	1	Lehrer	老师	Professor	教授	Ingenieur	工程师	Brille	眼镜	Essig	米醋	Tube	调味瓶
	2	Ketchup	番茄酱	Senf	芥末	Essig	米醋	Tube	调味瓶	Ingenieur	工程师	Brille	眼镜
7	1	Jongleur	杂耍者	Akrobat	杂技演员	Clown	小丑	Zirkus	马戏团	Hacke	锄头	Scheune	谷仓
	2	Rasenmäher	割草机	Schaufel	铲子	Hacke	锄头	Scheune	谷仓	Clown	小丑	Zirkus	马戏团
8	1	Bauer	农夫	Jäger	猎人	Fischer	渔夫	Hund	小狗	Tinte	墨水	Pinsel	毛笔
	2	Aquarellfarbe	水彩	Ölfarbe	油彩	Tinte	墨水	Pinsel	毛笔	Fischer	渔夫	Hund	小狗
9	1	Soldat	士兵	Pilot	飞行员	Matrose	水手	Uniform	制服	Kühlschrank	冰箱	Geschirr	餐具
	2	Spülmaschine	洗碗机	Mikrowelle	微波炉	Kühlschrank	冰箱	Geschirr	餐具	Matrose	水手	Uniform	制服
10	1	Spatz	麻雀	Krähe	乌鸦	Taube	鸽子	Nest	鸟窝	Geige	提琴	Noten	乐谱
	2	Flöte	长笛	Klavier	钢琴	Geige	提琴	Noten	乐谱	Taube	鸽子	Nest	鸟窝
11	1	Zebra	斑马	Giraffe	长颈鹿	Elefant	大象	Zoo	动物园	Tacker	订书机	Büro	办公室
	2	Locher	打孔机	Spitzer	转笔刀	Tacker	订书机	Büro	办公室	Elefant	大象	Zoo	动物园
12	1	Fuchs	狐狸	Bär	狗熊	Wolf	豺狼	Höhle	洞穴	Bonbon	糖果	Konditorei	糕点店
	2	Torte	蛋糕	Gebäck	饼干	Bonbon	糖果	Konditorei	糕点店	Wolf	豺狼	Höhle	洞穴
13	1	Kaninchen	兔子	Eichhörnchen	松鼠	Hamster	仓鼠	Wald	森林	Bus	公车	Gepäck	行李
	2	Flugzeug	飞机	Taxi	出租车	Bus	公车	Gepäck	行李	Hamster	仓鼠	Wald	森林
14	1	Schildkröte	乌龟	Schnecke	蜗牛	Frosch	青蛙	Aquarium	水族馆	Lineal	直尺	Architekt	建筑师
	2	Winkelmesser	角尺	Zirkel	圆规	Lineal	直尺	Architekt	建筑师	Frosch	青蛙	Aquarium	水族馆
15	1	Mücke	苍蝇	Motte	蛾子	Spinne	蜘蛛	Lampe	灯	Zahnpasta	牙膏	Schaum	泡沫
	2	Shampoo	洗发水	Seife	肥皂	Zahnpasta	牙膏	Schaum	泡沫	Spinne	蜘蛛	Lampe	灯
16	1	Biene	蜜蜂	Libelle	蜻蜓	Käfer	甲虫	Blume	花朵	Hammer	锤子	Werkstatt	作坊
	2	Säge	锯子	Beil	斧头	Hammer	锤子	Werkstatt	作坊	Käfer	甲虫	Blume	花朵
17	1	Bleistift	铅笔	Kugelschreiber	圆珠笔	Kreide	粉笔	Schule	学校	Nagellack	指甲油	Spiegel	镜子
	2	Mascara	睫毛膏	Lippenstift	口红	Nagellack	指甲油	Spiegel	镜子	Kreide	粉笔	Schule	学校
18	1	Stiefel	靴子	Sandale	凉鞋	Sportschuh	运动鞋	Fuß	足部	Toaster	烤面包机	Flamme	炉火
	2	Backofen	烤箱	Herd	炉灶	Toaster	烤面包机	Flamme	炉火	Sportschuh	运动鞋	Fuß	足部
19	1	Hemd	衬衫	Hose	裤子	Rock	裙子	Bügel	熨斗	Kerze	蜡烛	Dunkelheit	黑暗
	2	Fackel	火炬	Laterne	花灯	Kerze	蜡烛	Dunkelheit	黑暗	Rock	裙子	Bügel	熨斗
20	1	Schal	头巾	Krawatte	领带	Halstuch	围巾	Hals	脖子	Bambus	竹子	Schatten	树荫
	2	Pinie	松树	Palme	棕榈	Bambus	竹子	Schatten	树荫	Halstuch	围巾	Hals	脖子
21	1	Handschuh	手套	Fäustling	指套	Socke	袜子	Finger	指头	Hering	青鱼	Angel	钓具
	2	Lachs	三文鱼	Karpfen	鲤鱼	Hering	青鱼	Angel	钓具	Socke	袜子	Finger	指头
22	1	Jacke	夹克	Mantel	外套	Pullover	毛衣	Garderobe	寄存处	Becher	杯	Suppe	汤水
	2	Schüssel	饭碗	Teller	盘子	Becher	杯	Suppe	汤水	Pullover	毛衣	Garderobe	寄存处

23	1	Orange	橙子	Banane	香蕉	Ananas	菠萝	Geschäft	商店	Badewanne	浴缸	Handtuch	毛巾
	2	Dusche	淋浴	Spüle	水槽	Badewanne	浴缸	Handtuch	毛巾	Ananas	菠萝	Geschäft	商店
24	1	Birne	杏子	Apfel	苹果	Aprikose	鸭梨	Korb	果篮	Leopard	豹子	Käfig	笼子
	2	Löwe	狮子	Tiger	老虎	Leopard	豹子	Käfig	笼子	Aprikose	鸭梨	Korb	果篮
25	1	Pflaume	李子	Kirsche	樱桃	Erdbeere	草莓	Plantage	农场	Sänger	歌手	Bühne	舞台
	2	Tänzer	舞者	Schauspieler	演员	Sänger	歌手	Bühne	舞台	Erdbeere	草莓	Plantage	农场
26	1	Zwiebel	洋葱	Tomate	番茄	Paprika	胡椒	Küche	厨房	Sprachrohr	扩音器	Konzert	音乐会
	2	Mikrofon	麦克风	Lautsprecher	扬声器	Sprachrohr	扩音器	Konzert	音乐会	Paprika	胡椒	Küche	厨房
27	1	Kartoffel	土豆	Gurke	黄瓜	Karotte	萝卜	Markt	市场	Radio	收音机	Kabel	电缆
	2	Stereoanlage	音响	Fernseher	电视	Radio	收音机	Kabel	电缆	Karotte	萝卜	Markt	市场
28	1	Spinat	菠菜	Erbse	豌豆	Kohl	卷心菜	Garten	菜园	Nagel	钉子	Mechaniker	技工
	2	Dübel	销子	Schraube	螺丝	Nagel	钉子	Mechaniker	技工	Kohl	卷心菜	Garten	菜园
29	1	Likör	甜酒	Wein	红酒	Bier	啤酒	Kneipe	酒吧	Pflug	犁	Heu	干草
	2	Mistgabel	干草叉	Rechen	耙子	Pflug	犁	Heu	干草	Bier	啤酒	Kneipe	酒吧
30	1	Limonade	柠檬水	Saft	果汁	Wasser	白水	Glas	玻璃杯	Panzer	坦克	Gelände	场地
	2	Bagger	挖掘机	Traktor	拖拉机	Panzer	坦克	Gelände	场地	Wasser	白水	Glas	玻璃杯
31	1	Burg	城堡	Palast	宫殿	Schloss	王宫	Hofdame	宫女	Computer	计算机	Student	学生
	2	Kopierer	复印机	Taschenrechner	计算器	Computer	计算机	Student	学生	Schloss	王宫	Hofdame	宫女
32	1	Theater	剧院	Kino	影院	Museum	博物馆	Kasse	售票处	Bauch	肚子	Masseur	按摩师
	2	Rücken	后背	Schulter	肩膀	Bauch	肚子	Masseur	按摩师	Museum	博物馆	Kasse	售票处
33	1	Laken	床单	Kissen	枕头	Decke	毯子	Nacht	夜晚	Filet	火腿	Frühstück	早餐
	2	Wurst	香肠	Speck	熏肉	Filet	火腿	Frühstück	早餐	Decke	毯子	Nacht	夜晚
34	1	Teppich	地毯	Rollo	百叶窗	Vorhang	窗帘	Zimmer	房间	Ohr	耳朵	Medikament	药
	2	Nase	鼻子	Mund	嘴巴	Ohr	耳朵	Medikament	药	Vorhang	窗帘	Zimmer	房间
35	1	Krug	罐子	Flasche	瓶子	Kanne	水罐	Milch	牛奶	Leder	皮革	Nadel	缝衣针
	2	Seide	丝绸	Wolle	毛料	Leder	皮革	Nadel	缝衣针	Kanne	水罐	Milch	牛奶
36	1	Blumentopf	花盆	Gießkanne	喷壶	Eimer	水桶	Pflanze	植物	Haar	毛发	Rasierklinge	刀片
	2	Bart	胡子	Stoppel	胡茬	Haar	毛发	Rasierklinge	刀片	Eimer	水桶	Pflanze	植物
37	1	Zeitschrift	期刊	Zeitung	报纸	Magazin	杂志	Reporter	记者	Nelke	康乃馨	Fensterbrett	窗台
	2	Orchidee	兰花	Geranie	天竺葵	Nelke	康乃馨	Fensterbrett	窗台	Magazin	杂志	Reporter	记者
38	1	Pille	丸药	Salbe	软膏	Tablette	片剂	Arzt	医师	Pfanne	煎锅	Koch	厨师
	2	Backform	饼铛	Topf	锅子	Pfanne	煎锅	Koch	厨师	Tablette	片剂	Arzt	医师
39	1	Gabel	叉子	Messer	刀子	Löffel	汤匙	Fleisch	肉食	Wecker	闹钟	Zeiger	指针
	2	Stoppuhr	秒表	Taschenuhr	手表	Wecker	闹钟	Zeiger	指针	Löffel	汤匙	Fleisch	肉食
40	1	Eiche	橡树	Birke	白桦	Ahorn	枫树	Vogel	鸟类	Handtasche	手提袋	Bahnhof	火车站
	2	Koffer	箱子	Rucksack	背包	Handtasche	手提袋	Bahnhof	火车站	Ahorn	枫树	Vogel	鸟类
41	1	Telefon	电话	Handy	手机	Fax	传真	Rechnung	帐单	Lupe	放大镜	Auge	眼睛
	2	Mikroskop	显微镜	Fernglas	望远镜	Lupe	放大镜	Auge	眼睛	Fax	传真	Rechnung	帐单
42	1	Führerschein	驾照	Ausweis	身份证	Reisepass	护照	Polizei	警察	Kaffee	咖啡	Tasse	杯子
	2	Kakao	可可	Tee	茶	Kaffee	咖啡	Tasse	杯子	Reisepass	护照	Polizei	警察
43	1	Käse	奶酪	Butter	黄油	Sahne	奶油	Kuh	奶牛	Smaragd	祖母绿	Juwelier	珠宝商
	2	Diamant	钻石	Rubin	红宝石	Smaragd	祖母绿	Juwelier	珠宝商	Sahne	奶油	Kuh	奶牛
44	1	Weizen	小麦	Roggen	黑麦	Reis	水稻	Mähdrescher	收割机	Postkarte	明信片	Postbote	邮差
	2	Telegramm	电报	Brief	书信	Postkarte	明信片	Postbote	邮差	Reis	水稻	Mähdrescher	收割机
45	1	Kamin	火炉	Klimaanlage	空调	Heizkörper	暖气	Wohnung	公寓	Stern	星星	Raumschiff	飞船
	2	Planet	行星	Mond	月亮	Stern	星星	Raumschiff	飞船	Heizkörper	暖气	Wohnung	公寓

APPENDIX C

Transcript of the test phase instructions used in Experiments 2 and 4

Recognition can be associated with two different kinds of awareness:

1. Quite often recognition of the object brings back to mind specific memories, connected to the object, e.g. you recognize one's face and you **remember** talking to this person at a party previous night.
2. At other times, recognition brings back to mind nothing about what it is you recognize, e.g., the person's face looks familiar to you and you **know** that you saw this face before but no further details come to your mind.

The same kinds of awareness are associated with recognizing word pairs that you saw in the study phase. For some word pair that you see, you would remember the specific details from the study phase: pictures that you imagined; how you rated the clarity of the images; the moment in the study phase the word pair appeared, etc.This means, you **remember** this word pair. In other cases, a word pair would look familiar and you would **know** that you saw it before, but no further details about this word pair would come to your mind.

You have the following two tasks in the test phase.

Task 1
You will simultaneously see three words, e.g.

Word 1 Word 2
Word 3

One of the two upper words (Word 1 or Word 2) was paired with the lower word (Word 3) in the study phase. Your task is to recognize the word pair that you saw in the study phase.

Please, press the
GREEN key, if you saw the left word pair (Word1 – Word3) in the study phase.
YELLOW key, if saw the right word pair (Word2 – Word3) in the study phase.

Task 2
After you decided which word pair you saw during the study phase, a message will appear on the screen:

???
Guess – Know – Remember

Please, press “Remember” key if you **remember** seing this word pair;
If you simply **know** that you saw this wordpair, press “Know” key.
If you had to **guess** to provide an answer, press the “Guess” key. (Please, try to guess as little as possible!)

APPENDIX D

Extended views of the ERP waveforms in Experiments 1 and 3: recordings from 46 electrode sites

Figure D.1: Experiment 1. ERP waveforms elicited by correctly responded to old and new word pairs in the categorical condition on 46 electrode sites.

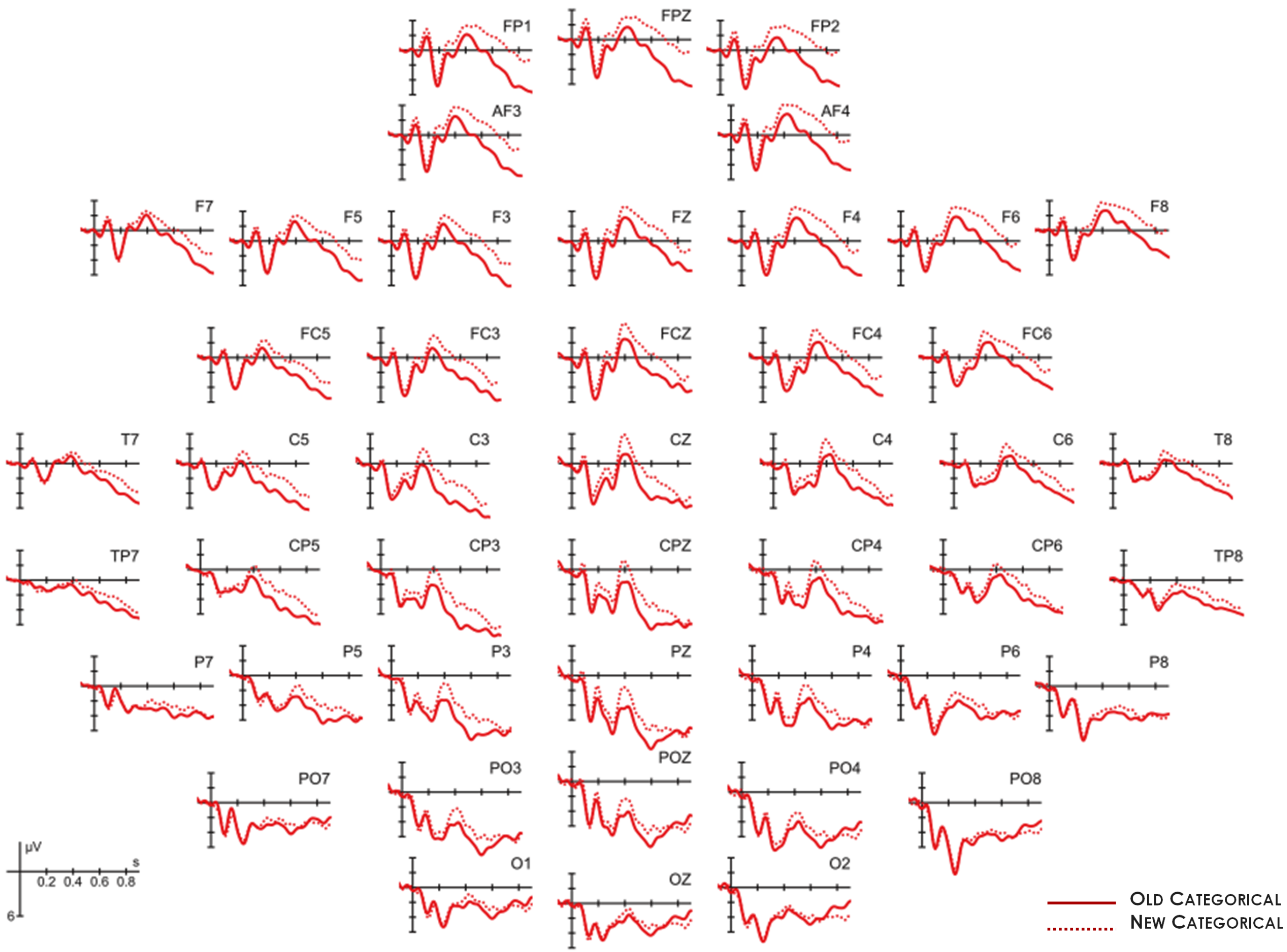


Figure D.2: Experiment 1. ERP waveforms elicited by correctly responded to old and new word pairs in the thematic condition on 46 electrode sites.

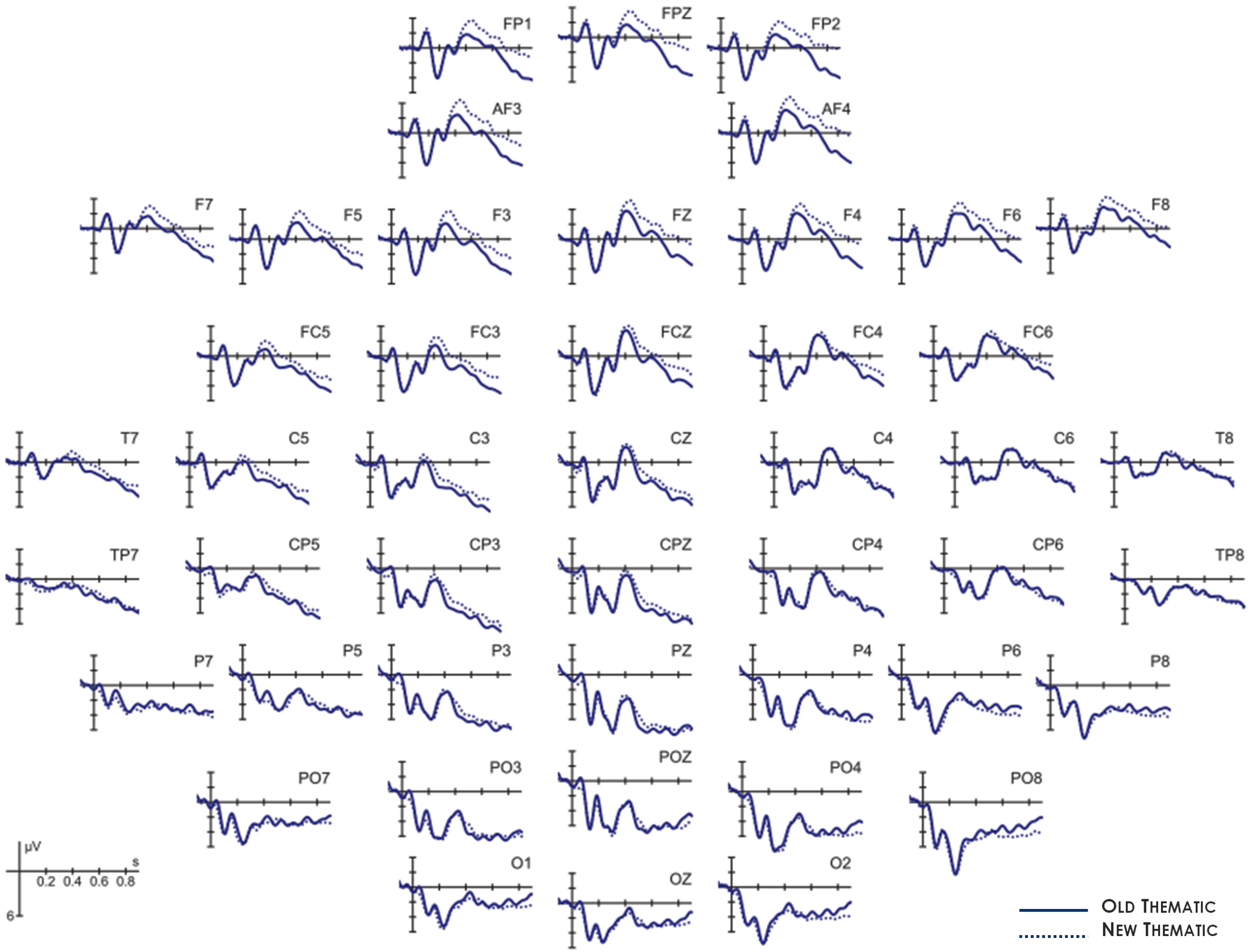


Figure D.3: Experiment 1. ERP waveforms elicited by correctly responded to old and new word pairs in the unrelated condition on 46 electrode sites (the data from 13 participants).

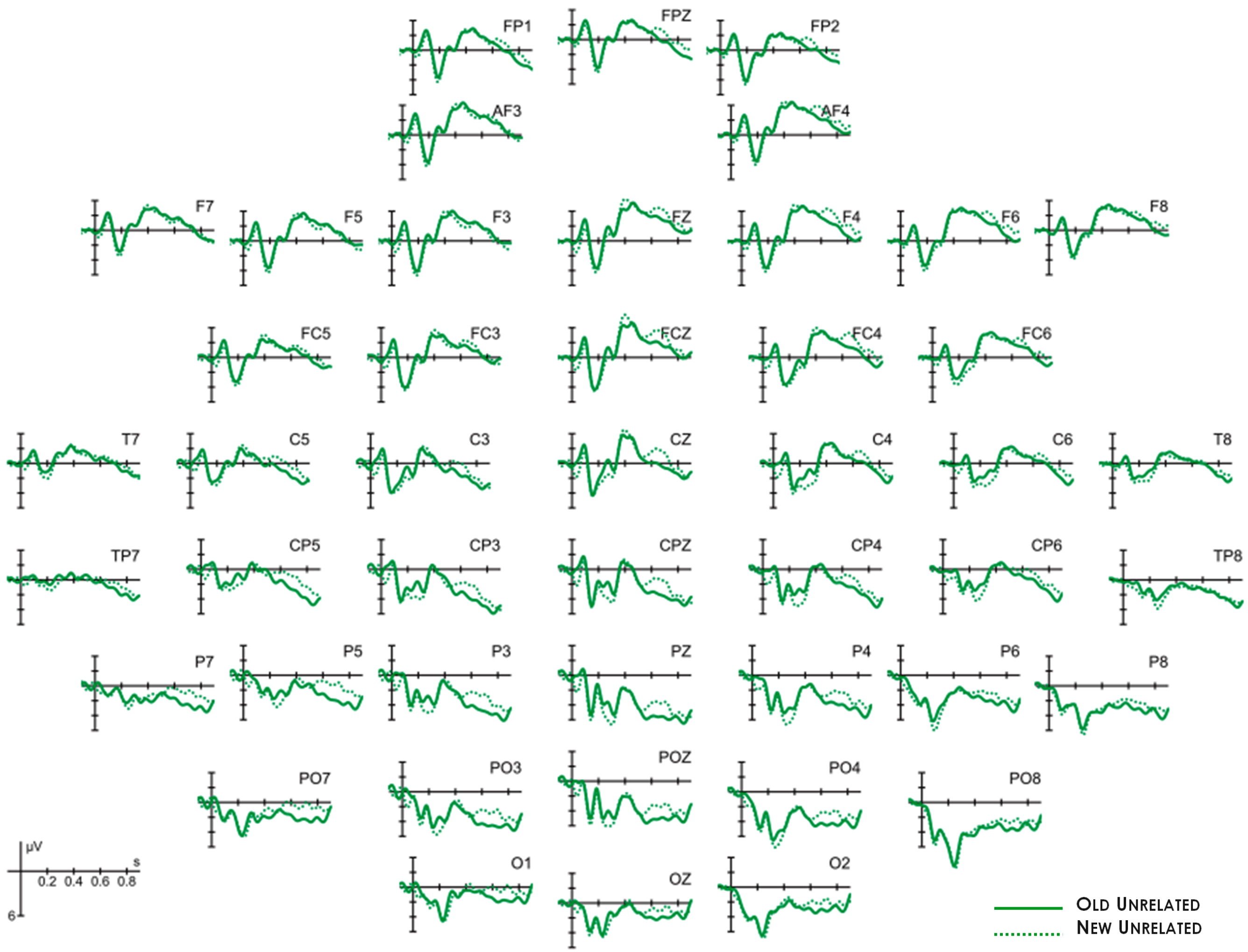


Figure D.4: Experiment 1. ERP waveforms elicited by correctly responded to new word pairs in the categorical, thematic and unrelated conditions on 46 electrode sites.

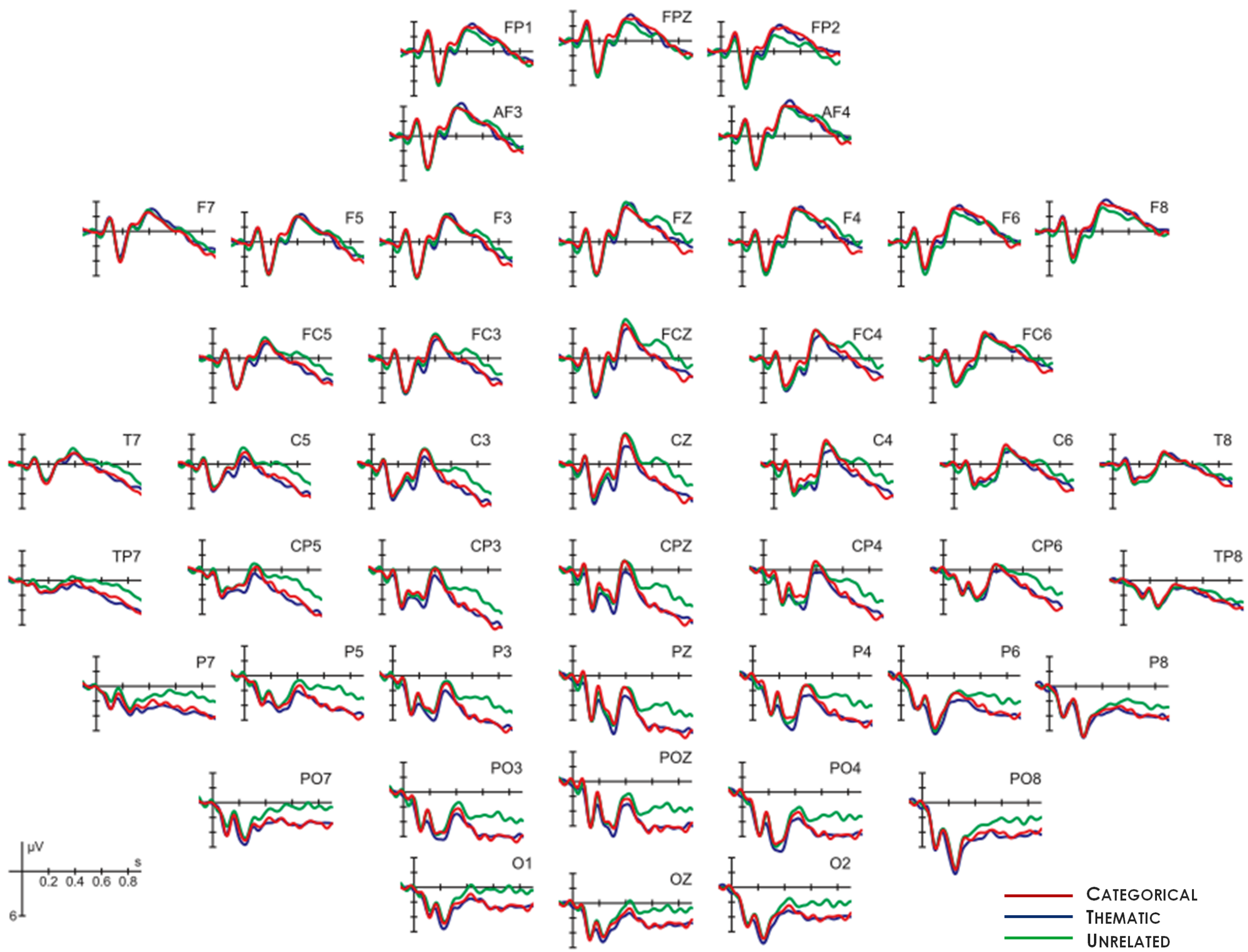


Figure D.5: Experiment 1. Study-phase ERPs associated with word pairs subsequently correctly endorsed as old at test (46 electrode sites). Recordings were locked to the onset of the second word in each pair.

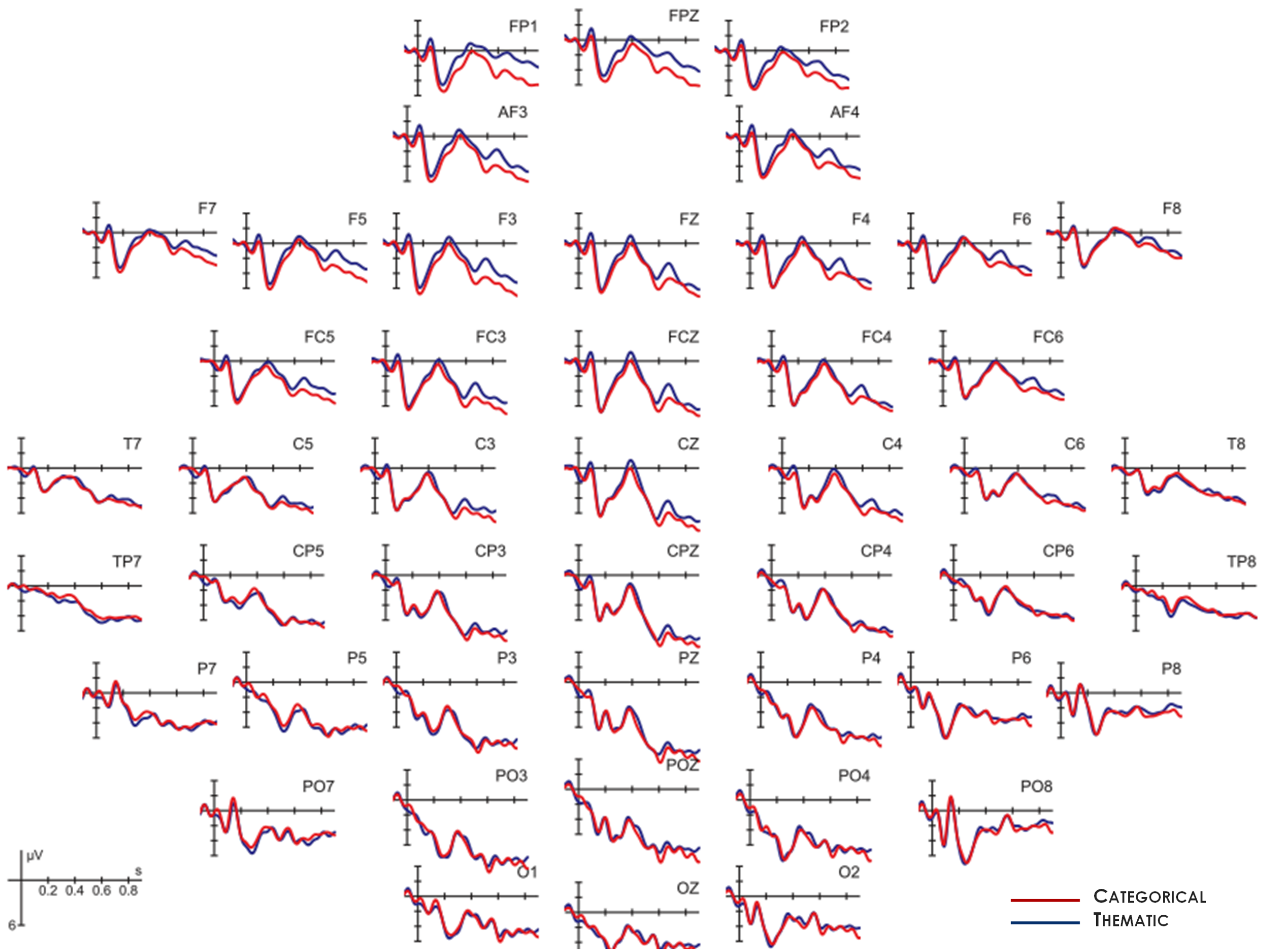


Figure D.6: Experiment 3. ERP waveforms elicited by correctly responded to old and new word pairs in the categorical condition on 46 electrode sites.

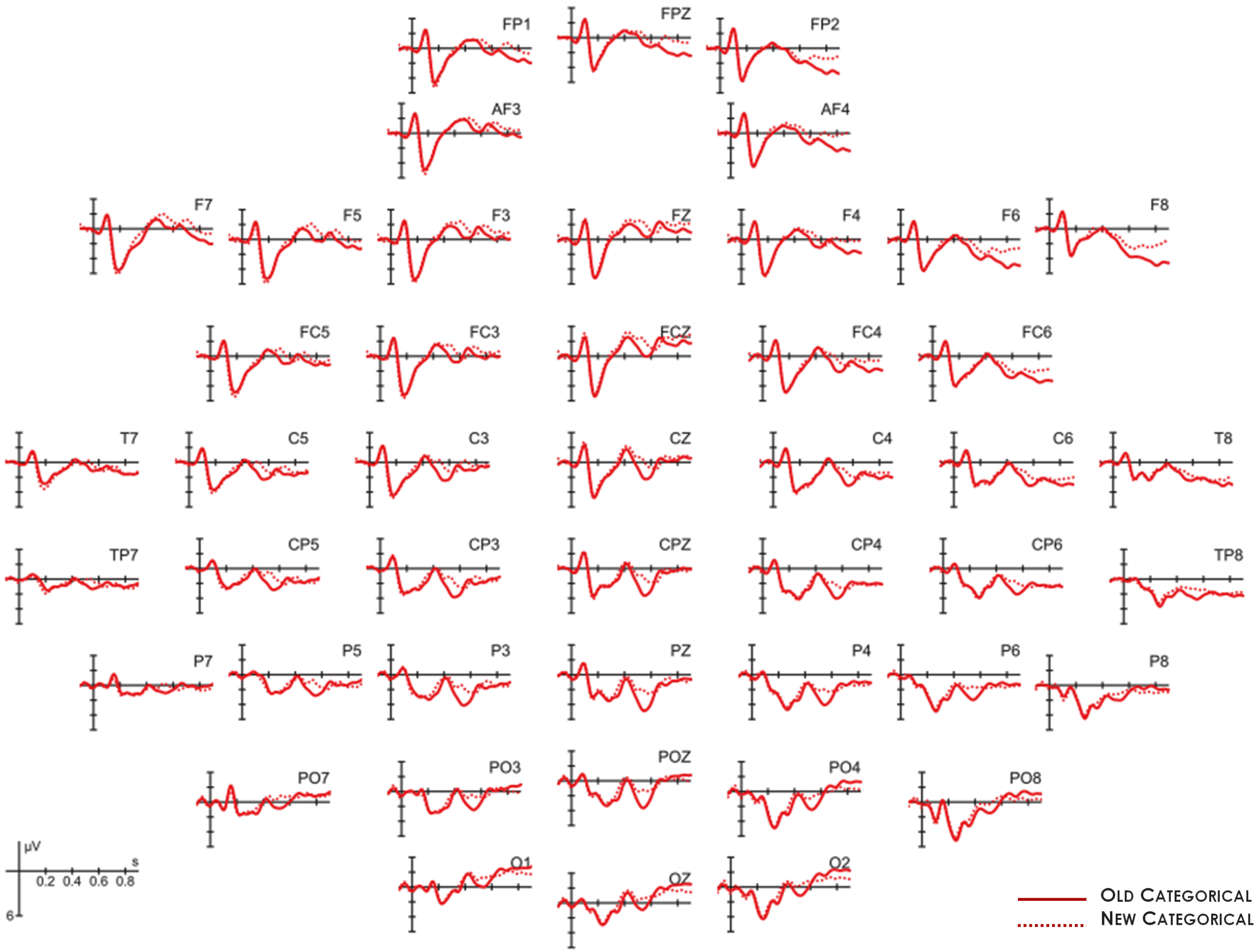


Figure D.7: Experiment 3. ERP waveforms elicited by correctly responded to old and new word pairs in the thematic condition on 46 electrode sites.

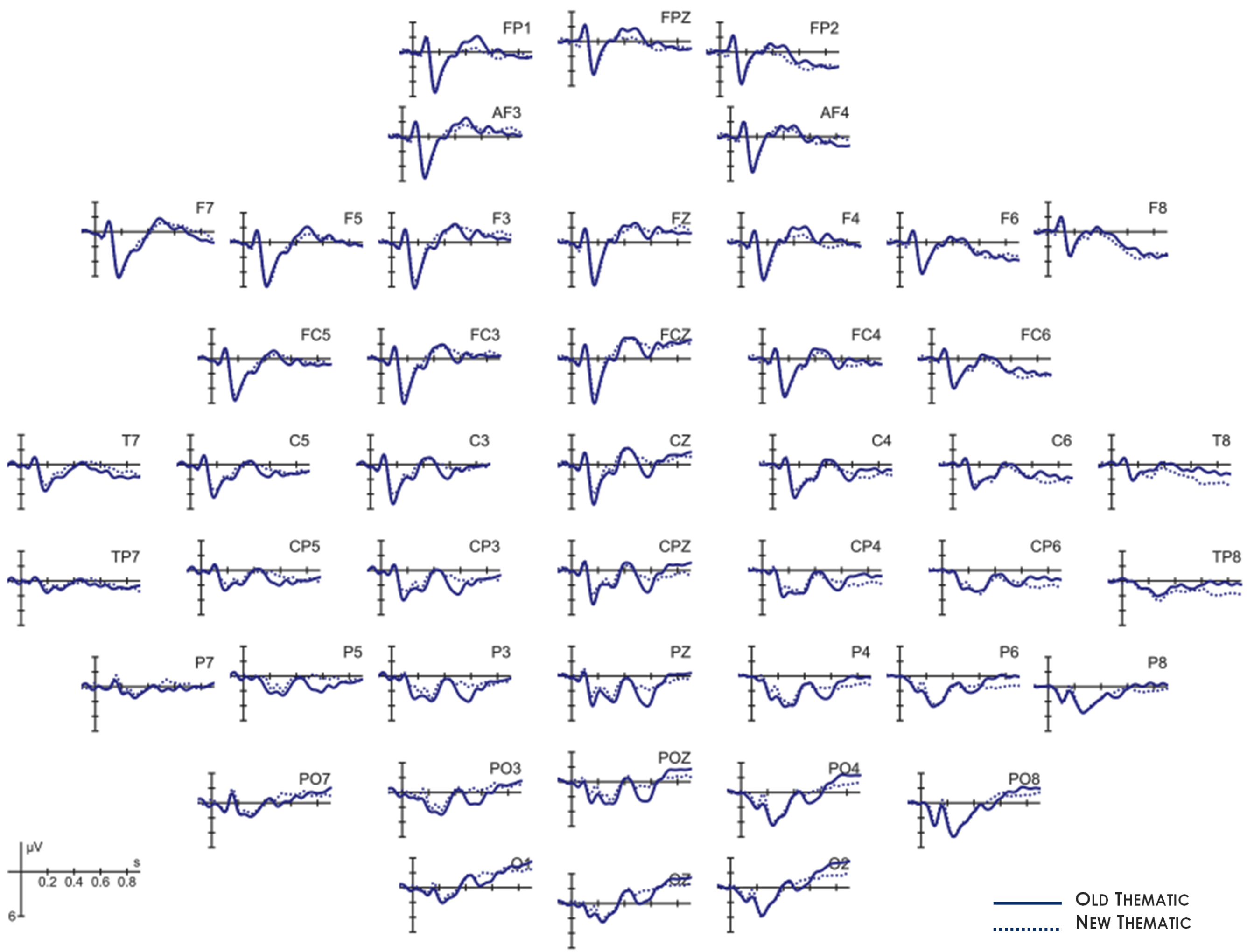
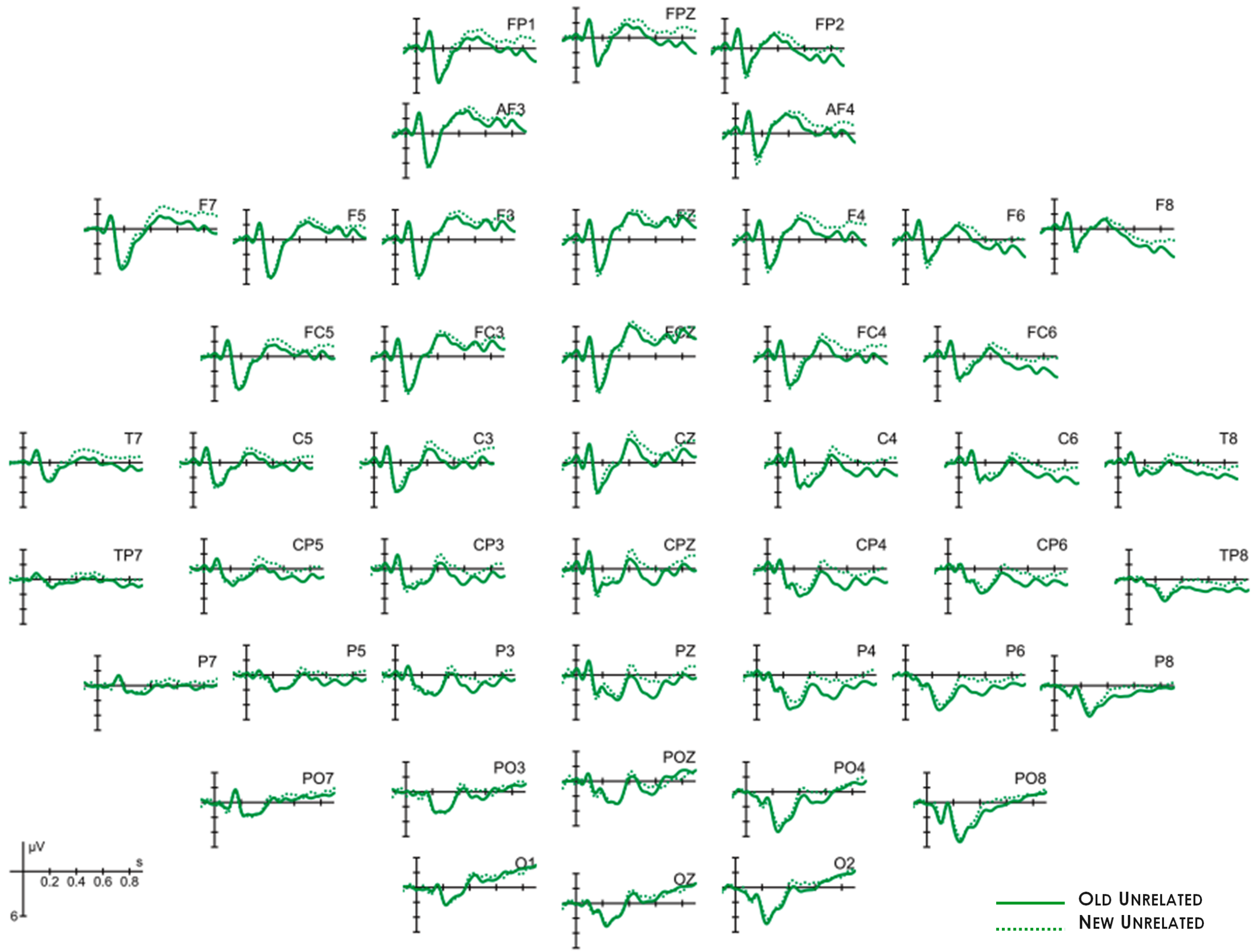


Figure D.8: Experiment 3. ERP waveforms elicited by correctly responded to old and new word pairs in the unrelated condition on 46 electrode sites.



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Publications (peer-reviewed)

Kriukova, O., Bridger, E. & Mecklinger, A. (submitted). Semantic relations differentially impact associative recognition memory: electrophysiological evidence.

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Other publications

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