

## Context effects on familiarity are familiarity effects of context — An electrophysiological study

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### Abstract

Within dual-process accounts of recognition memory, familiarity (as opposed to recollection) is often referred to as a rather automatic and context-free process. Thus, in episodic object recognition, familiarity and its electrophysiological ERP signature are supposed to index prior occurrence of an object independent of the context the object was originally encountered in, e.g., [Ecker, U.K.H., Zimmer, H.D., Groh-Bordin, C., in press. Color and context: An ERP study on intrinsic and extrinsic feature binding in episodic memory. *Mem. Cogn.*]. Yet, contextual sensitivity of familiarity has also been reported (e.g., [Tsvivilis, D., Otten, L.J., Rugg, M.D., 2001. Context effects on the neural correlates of recognition memory: An electrophysiological study. *Neuron* 31, 497–505.]). We argue that considering attentional and perceptual factors of target processing is vital in understanding these conflicting results. Presenting target objects on contextual landscape scenes, we introduced a cueing technique designed to focus subjects' attention on target processing. We demonstrate that context effects on familiarity are diminished if the attentional impact of contextual stimuli is experimentally controlled, arguing that contextual influences on object familiarity are indirect and mediated by factors such as salience and attentional capture. Results suggest that salient context stimuli may elicit an independent familiarity signal instead of directly impacting on the familiarity signal of the target object. We conclude that (a) object familiarity is in principle a rather automatic and context-free process, and that (b) the study of episodic memory can profit substantially from adopting a dynamic processing perspective. © 2007 Elsevier B.V. All rights reserved.

**Keywords:** Event-related potentials; Familiarity; Context effects; Recognition memory; Attention

### 1. Introduction

Human episodic memory is commonly studied by way of recognition memory tasks, in which the prior occurrence of stimuli is assessed. Past research has suggested that this ability draws on two distinct processes: familiarity and recollection. Familiarity refers to a general feeling of having encountered a person or specific object before, without conscious access to contextual details, such as the time or place of the encounter. Recollection, on the other hand, refers to the conscious retrieval of specific details related to the encoding episode. These specifics are not limited to spatiotemporal context, but may as

well consist in thoughts one had at the time of first encounter, or other items present at encoding. While introspectively appealing, this distinction has been experimentally supported by a wealth of findings from cognitive psychology (e.g., Gardiner et al., 1996; for a review see Yonelinas, 2002) and clinical neuropsychology (e.g., Mayes et al., 2002; Srinivas and Verfaellie, 2000). Functionally, findings do in fact suggest that familiarity is a rather automatic process sufficient for mere item memory, whereas recollection is a rather controlled process needed for contextual integration (binding) and source memory (for an overview of the role of binding in memory, see Zimmer et al., 2006). Neuroscientifically, the two processes have been associated with different brain regions (Aggleton and Brown, 1999; Eldridge et al., 2000; Ranganath et al., 2004; Wan et al., 1999). Specifically, whereas familiarity memory often remains intact following hippocampus lesions – presumably relying on

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adjacent rhinal cortex – recollection is severely impaired (Mumby et al., 2002; Baddeley et al., 2001).

Most importantly for present purposes, familiarity and recollection have been associated with distinct electrophysiological signatures (Curran, 2000; Friedman and Johnson, 2000; Mecklinger, 2000, 2006; see also Düzel et al., 2001). The ERP correlate of familiarity is a midfrontal old–new effect occurring at approximately 300–500 ms post-stimulus onset, in which repeatedly presented (i.e., old) items elicit a more positive-going potential than new items (the FN400 effect). Recollection is associated with a delayed and topographically different effect usually visible at (left-)parietal electrodes from around 500 to 800 ms (the LPC effect).

In a recent recognition memory study (Ecker et al., *in press*), we were able to show that familiarity and the associated FN400 effect are sensitive to study–test manipulations of intrinsic item features (e.g., the color of an object), but insensitive to contextual manipulations. That is, the FN400 old–new effect was diminished if the color of objects was changed from study to test, but it was not affected by a change of arbitrary background shapes, even though this specific context information was available to subjects in a direct source memory test. In contrast, recollection and the associated LPC effect were affected by both item and contextual study–test changes. We concluded that familiarity is a context-free process matching conceptual and perceptual features of specified test stimuli and object memory representations (for more theoretical background, see also Ecker et al., 2004).

Yet, Tsivilis et al. (2001) did report a contextual influence on the FN400 effect. They had subjects study object images on highly salient landscape<sup>1</sup> scenes, and manipulated the Old/New status of objects, contexts, and their specific combinations, resulting in five test conditions: old objects presented on the Same background as at study (i.e., identical repetition), old objects presented on an old context, but Rearranged with respect to study, old objects presented on new backgrounds (Old/New), and new objects presented on either old (New/Old) or new (New/New) backgrounds. Instructions were to judge the old/new status of objects, irrespective of context (inclusion task). They reported an FN400 effect only for Same and Rearranged repetitions, but not for Old/New items.

At first glance, this finding speaks against the view that familiarity is an acontextual process. Interestingly, however, Same and Rearranged conditions did not differ in their ERP effects,<sup>2</sup> suggesting that the FN400 signal was not based on activation of an integrated representation of item and context (but see Curran et al., 2006). Tsivilis et al. (2001) concluded that the FN400 effect indexes some process “downstream” of familiarity and/or rather reflected novelty processing.

An alternative interpretation of the lacking effect for Old/New items stems from a careful examination of the processes

leading up to a familiarity judgment. Most recognition memory studies use single, stand-alone items, whereas in reality the visual environment at any given time usually consists of scenes of many different overlapping objects and backgrounds. Thus, attention and perception processes first need to establish stable and bound representations of what is to be assessed. This implies that there is a “race” of features and objects for representation and (conscious) perception. Usually, this race will be won by the object that is either most salient for any given reason (e.g., size, color, brightness, occlusion, figure–ground phenomena may all play a role for attentional capture and the speed of initial processing, independent of task-relevance; cf. Brockdorff and Lamberts, 2000; Hickey et al., 2006; Lamberts, 1998) or it will be won by the object that has a certain attentional top-down advantage (biased competition; cf. Beck and Kastner, 2005). Then, the familiarity signal results from a comparison of object representations in perception (object file; cf. Treisman, 2006) and episodic memory (object token; cf. Ecker et al., 2004). Assuming that this signal is an encapsulated signal of the object and its intrinsic features, context information should not have any influence (Cabeza, 2006; Ecker et al., *in press*; Yonelinas et al., 1999). The Tsivilis et al. (2001) data seemingly stand in contrast to this notion; what might have happened at least in a subset of their trials is that memory was initially not cued with the actual target object, but the highly salient context. That is, if the context stimulus won the competition for representation due to its advantage in salience and was thus perceived first, it initially affected familiarity processing before an attention shift put the actual target into focus, allowing subjects to perform the task at a high level of accuracy. In other words, an alternative interpretation of the FN400 data pattern is that contexts in the Tsivilis et al. study were so salient that they achieved object status themselves, hence becoming “more than context” and eliciting an own electrophysiological familiarity signal. It seems likely that at test, attention was automatically drawn to these large and highly salient landscapes, so the cognitive system was not able to treat them as contextual noise irrelevant for the decision. Therefore, the effect pattern may not represent a direct influence of context on target familiarity, but rather an independent familiarity signal of the context (or rather, a lack of such a signal in the case of a new context stimulus).

The aim of the present study was to test this idea by adopting the Tsivilis et al. (2001) design and manipulating the potential of the contexts to automatically capture attention. This was done by implementing a two-group design: one group followed the Tsivilis et al. procedure, whereas we introduced a cueing technique in the other group, following spotlight/zoom lens conceptions of visual attention (Cave and Kosslyn, 1989; Müller et al., 2003; Paul and Schyns, 2003; Posner et al., 1980; Yantis and Jonides, 1990; see below for details).

## 2. Design, procedure and methods

The design followed the one by Tsivilis et al. (2001) in many aspects. Throughout the experiment, object images of varying

<sup>1</sup> Note that in the following, the terms landscape and context will be used somewhat interchangeably, although it should be stressed that the utilized landscapes are a very specific operationalization of context.

<sup>2</sup> Note that there was a difference in reaction times, i.e., RT was lower for Same vs. Rearranged.

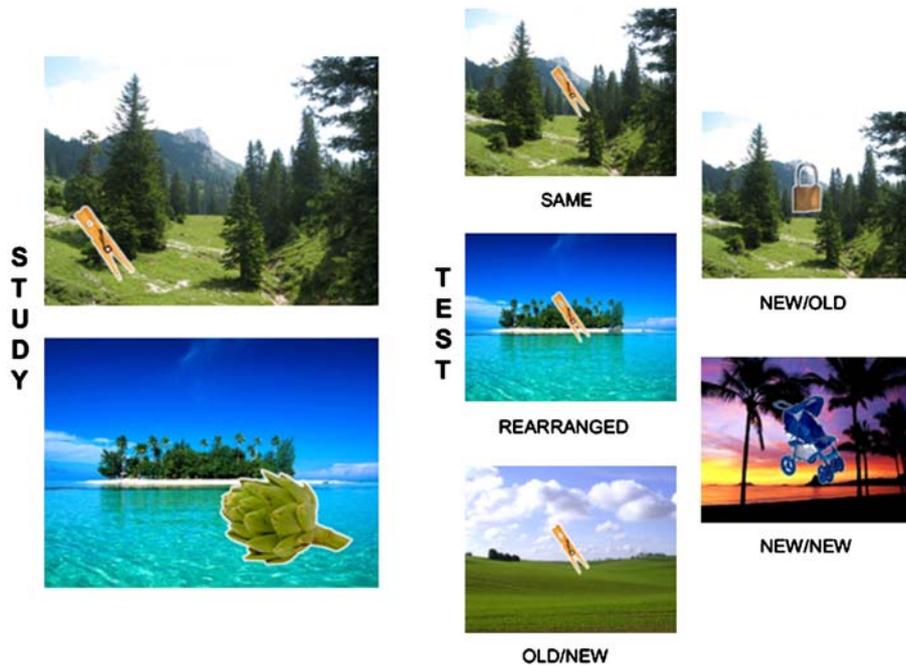


Fig. 1. Sample items and test conditions.

sizes<sup>3</sup> (max. expansion 90–160 pixels) were presented superimposed on rectangular background images (300×400 pixels). The object images depicted both natural and man-made items, including animals, food items, and tools. The background images depicted landscapes with the limitation that no buildings, animals, or people appeared. Landscapes were always presented centrally, on a 17 in. flat screen monitor. The experiment took place in a sound- and electromagnetically shielded cabin, subjects sat about 80 cm from the screen. Objects took up a visual angle of approximately 2–4°; the angle for landscapes was approximately 9×7°.

Altogether, 180 object images and 105 landscapes were used. For every participant, one of seven sets of 15 contexts each was randomly selected for the study phase. Subjects studied 120 objects, each presented on one of the four quadrants of the 15 different landscape images (i.e., every selected context appeared 8 times in the study phase). Subjects' task was to mentally place the object anywhere within the landscape scene, and to think of a reason or narrative why they placed it there. Additionally, and departing from the original Tsivilis et al. (2001) study, instructions were given to memorize the material. Presentation rate was self-paced; however, every item was presented at least 3000 ms. The ISI was 500 ms, in which a fixation cross was presented centrally. A practice phase with four items not appearing in the actual experiment preceded the study phase; during practice, subjects spoke out loud the narrative, which was controlled by the experimenter. Between the practice and study phase, subjects were presented with all

fifteen contexts to appear in the study phase for the purpose of familiarization; each background was shown for 2000 ms, with an ISI of 500 ms.

Preceding the actual test phase, another practice phase with five trials – one from each test condition, using the material of the first practice phase plus new items also not included in the experiment proper – was carried out. At test, all objects were presented centrally on the background image. There were five test conditions: 30 old objects appeared on the background they had already appeared on during study (Same), 30 old objects were presented on an old but different background (Rearranged), and 60 old objects were presented on new backgrounds (Old/New). Additionally, 30 new objects appeared on old (New/Old) and new (New/New) backgrounds, respectively (see Fig. 1). All old contexts appeared twice per pertinent condition (i.e., Same, Rearranged, and New/Old). The task was an inclusion task, that is, subjects were to classify all repeated objects as old, irrespective of context or context changes. Throughout the experiment, there were pauses after every 60 items for subjects to relax their eyes; there was one filler item at the beginning of each test block of 60 trials.

There were two groups of subjects. For the NoCue group, the trial course was as follows: after a fixation cross (1500 ms), the test item was presented for 1000 ms and subjects were to respond as quickly as possible with a maximum response time of 2000 ms. The test item disappeared with the response (or after presentation time had elapsed), and a central x appeared for another 1000 ms. For the Cue group, the procedure was the same, except that the fixation cross was only presented for 500 ms, and instead a cue was presented for 1000 ms, immediately preceding the test item. The cue was a gray rectangle with a red frame, exactly encasing the following target object. Subjects of the Cue group were told that the cue would help them focus their

<sup>3</sup> Note that the only reason for different sizing of objects was the application of the cueing technique — if all objects were virtually the same size, cues would not be very helpful. There were no study–test size manipulations.

attention on the object and ignore the irrelevant context. The cueing technique thus served to counteract early bias effects of salience on representational competition by strengthening bottom-up and top-down attention focusing (cf. Cave and Kosslyn, 1989). Predictions were that the Tsivilis et al. FN400 effect pattern could be replicated in the NoCue group, whereas for the Cue group, equivalent FN400 old–new effects were predicted for the three conditions featuring old objects (Same–Rearranged–Old/New).

After the experiment proper, there was another test designed to directly tap source memory, that is, whether or not subjects had associated the objects with the specific contexts. This was a two-alternative forced-choice associative recognition test: every old test object was presented together with two landscape scenes beneath it. One of the contexts was the same as in the study phase, the other was also an old context (i.e., one of the 15 that had appeared in the study phase), but one that had not been presented with the specific object before — neither in the study phase, nor in the Rearranged condition of the test phase. Subjects were to indicate on which context the specific object had been presented at study.

Thirty-two students of Saarland University – sixteen per group – took part in this study and were paid for their participation. Mean age, age range, and number of females was 26, 20–32, and 10 for the NoCue group, and 24, 20–27, and 9 for the Cue group. One participant of the NoCue group had to be excluded from analysis due to excessive EEG artifact.

### 2.1. EEG/ERP methods

EEG was recorded from 63 Ag/AgCl electrodes (Electro-Cap International Inc., Eaton, OH) with a sampling rate of 250 Hz. Signals were referenced to left mastoid, but re-referenced offline to linked mastoids. EOG artifacts picked up by four ocular electrodes were corrected offline (Gratton et al., 1983). Before averaging, trials containing artifacts (lowest activity in successive 100 ms intervals  $\pm 0.5 \mu\text{V}$ , maximum amplitude in the segment  $\pm 100 \mu\text{V}$ , maximum voltage step between two successive sampling points  $40 \mu\text{V}$ , maximum difference between any two sampling points within an epoch

$100 \mu\text{V}$ ) were excluded (5.6% of trials). Digital bandpass filtering was applied between 0.2 and 20 Hz. ERPs were calculated by time-locked signal averaging, using the time window from  $-200$  to  $1300$  ms relative to stimulus onset. The minimum number of trials per condition for inclusion into a grand average was 16. Analysis was based on trials with correct old/new responses. The ERP methods are described in more detail elsewhere (Ecker et al., in press).

## 3. Results

### 3.1. Behavioral analysis

#### 3.1.1. Old–New recognition

Accuracy and reaction time data are depicted in Figs. 2 and 3. Repeated measures ANOVA on hit rates across groups indicated no interaction between condition (Same, Rearranged, Old/New) and group ( $F < 1$ ) and no significant main effect of group,  $F(1,29) = 2.02$ ,  $p > .1$ . In the NoCue group, the main effect of test condition was significant,  $F(2,28) = 3.34$ ,  $p < .05$ ; post-hoc testing (Tukey HSD) revealed a significant difference between Same and Old/New conditions,  $p < .04$ . In the Cue group, there was also a significant main effect of test condition,  $F(2,30) = 4.49$ ,  $p < .02$ . The Same condition differed significantly from Old/New,  $p < .02$ . Concerning the two New conditions, there was no significant across group interaction or main effect of group,  $F < 1$ . Performance rate (New/New vs. New/Old) did not differ in either group (both  $F < 1.16$ ,  $p > .2$ ).

Hit reaction time analysis yielded a marginally significant group main effect,  $F(1,29) = 2.83$ ,  $p = .10$ , indicating somewhat longer RTs in the Cue group (789 vs. 746 ms); there was no significant condition by group interaction,  $F(2,58) = 2.00$ ,  $p > .1$ . Yet, there was a significant main effect of condition in the NoCue group,  $F(2,28) = 5.04$ ,  $p < .02$ , whereas there was no such effect in the Cue group,  $F < 1$ . Post-hoc testing indicated that both Same and Rearranged RTs differed from the Old/New condition in the NoCue group,  $p < .02/.05$ ). Regarding RTs in the New conditions, there was no group main effect or interaction in the across group analysis ( $F < 1$ ). RTs differed in neither the NoCue ( $F < 1$ ) nor the Cue group ( $F(1,15) = 2.97$ ,  $p > .1$ ).

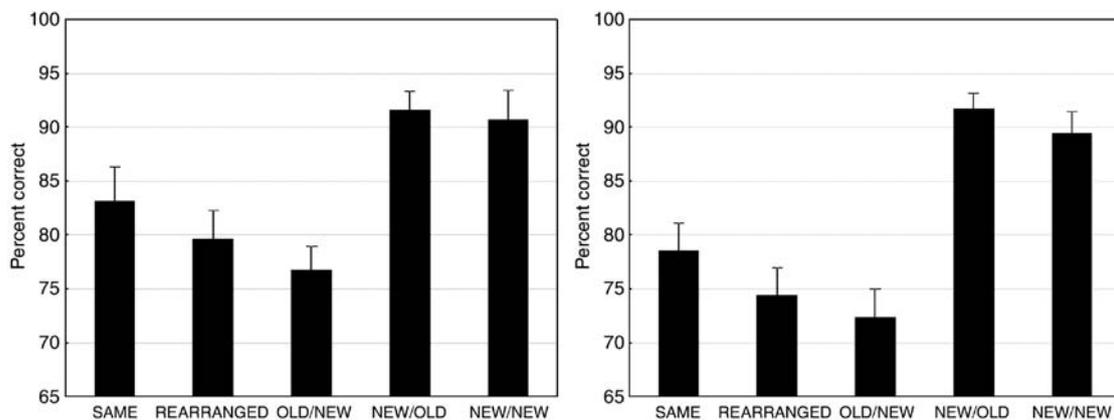


Fig. 2. Old/new recognition performance in the NoCue (left) and Cue (right) groups; vertical bars denote standard errors of the mean.

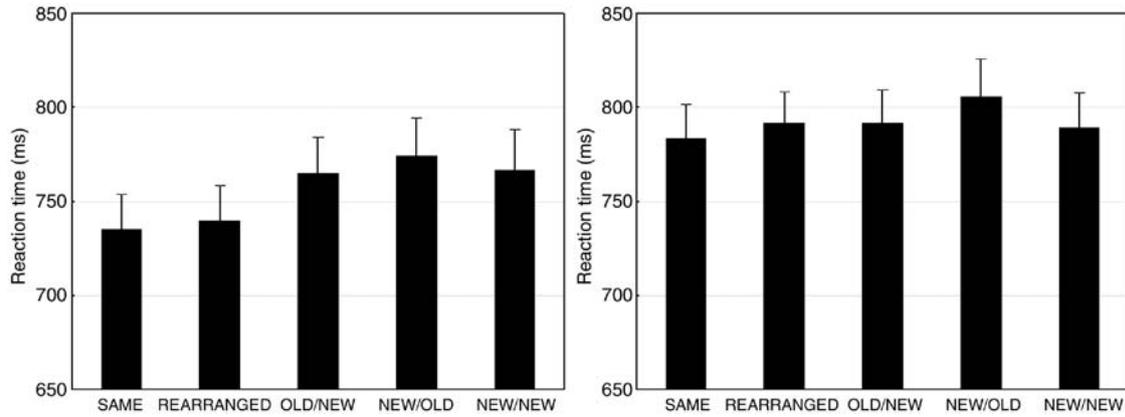


Fig. 3. Reaction times in the NoCue (left) and Cue (right) groups; vertical bars denote standard errors of the mean.

3.1.2. Forced-choice associative recognition

In the associative context recognition test at the end of the experiment, the mean rate of correct context-to-object assignment was .87 (MSE .02) and .86 (MSE .02) in the NoCue and Cue groups, respectively. Performances were consistently above chance in both groups, with  $t(14)=20.41, p<.001$  and  $t(15)=27.68, p<.001$ , respectively. There was no group difference in performance level,  $t<1$ , and no difference between mean reaction times (2635 vs. 2353 ms),  $t<1$ .

3.2. ERP analysis

Overall, the expected old–new effects (see Introduction) were observed (see Figs. 4 and 5). In the NoCue group, ERPs of

Same and Rearranged conditions differ from the other conditions around 400 ms, mainly at frontocentral recording sites (the FN400 effect). A more centro-posterior effect with a similar pattern arises somewhat later, between 500 and 700 ms (the LPC effect). In the Cue group, Same, Rearranged, and Old/New conditions elicit a more positive waveform than New/New (and New/Old) early on. The effect has a somewhat unusual topography, spreading along the midline from frontal to posterior electrodes. At later points in time, Same and Rearranged differ from New/New (with Old/New and New/Old in-between), again with a centro-posterior maximum.

Analyses were based on mean voltage amplitudes. Repeated measures ANOVAs corrected for non-sphericity using the Huynh–Feldt procedure were followed up by planned

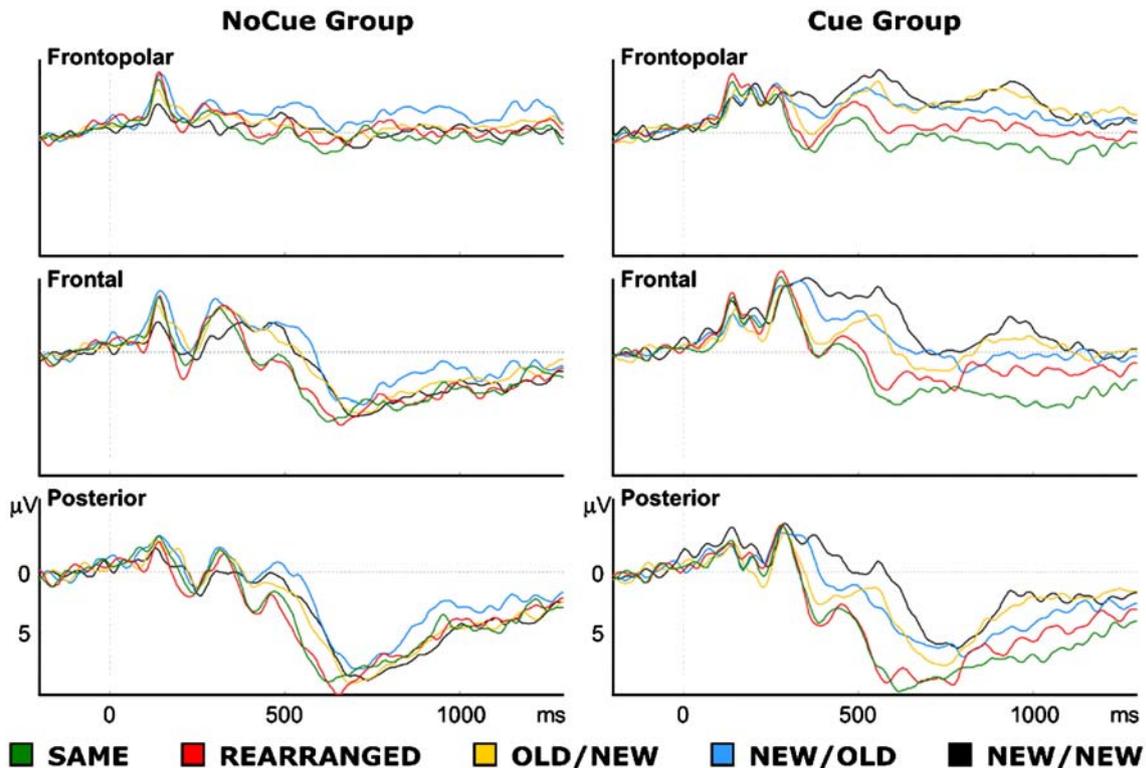


Fig. 4. Stimulus-locked grand average ERPs at central ROIs.

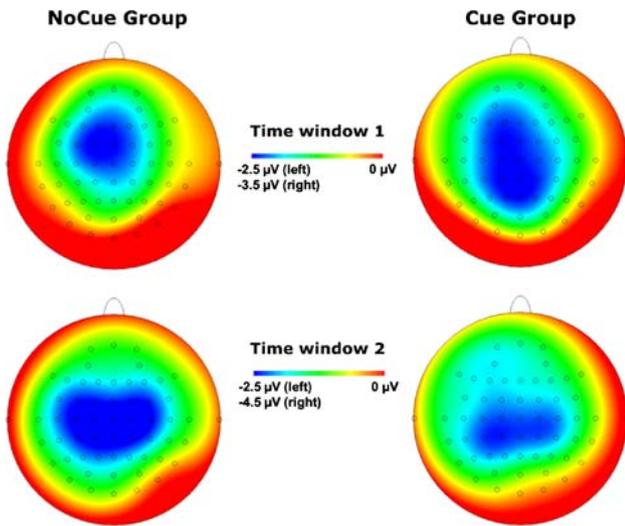


Fig. 5. Topographic maps depicting the differences in the NoCue group (left) between Same and Rearranged vs. Old/New, New/Old, and New/New conditions in time windows 1 (top) and 2 (bottom), and the differences in the Cue group (right) between Same, Rearranged, and Old/New vs. New/Old and New/New in time window 1 (top), and Same and Rearranged vs. Old/New, New/Old, and New/New in time window 2 (bottom).

comparisons, applying Holm’s sequential Bonferroni correction of alpha levels (Holm, 1979). Concerning the standard old–new effects, looking at peak latencies at respective regions of interest (see below), it became obvious that the FN400 peaked somewhat earlier in the Cue group as compared to the NoCue group (388 vs. 428 ms), whereas the LPC peaked later in the Cue group (639 vs. 612 ms). This interaction was significant in an across group ANOVA,  $F(1,29)=4.55, p<.05$ . Based on this interaction and visual inspection of the data, time window 1 was set to 300–450 ms in the Cue group and 350–500 ms in the NoCue group. Time window 2 was set to 550–750 ms and 500–700 in the Cue and NoCue groups, respectively.

As effects were generally largest along the midline, ERP analyses were carried out on central regions of interest (ROIs) only. ROIs were set a priori, but modified following visual inspection. Similar to the Tsivilis et al. (2001) study, three ROIs were utilized: frontopolar (Fpz, Fp1, Fp2), frontal (Fz, FC1, FC2), and posterior (Pz, CP1, CP2).

To avoid type I error due to post-hoc electrode selection, we first analyzed both early and late effects using data from all 56 head electrodes. For this purpose, we contrasted the two conditions most likely to show memory-related effects – Same and New/New – in group-wise condition by electrode analyses. In both groups and time windows was the condition by electrode interaction significant (NoCue group:  $F(55,770)=4.06/2.17, \epsilon=.17/.12, p<.05$ ; Cue group:  $F(55,825)=6.74/7.54, \epsilon=.16/.23, p<.01$ ). In an analysis across time windows, the time window by electrode by condition interaction was also significant in the Cue group,  $F(55,825)=3.05, \epsilon=.15, p<.01$ , but the interaction failed to reach significance in the NoCue group,  $F(55,770)=1.55, \epsilon=.07, p>.05$ . Despite this lack of support for distinct effects across time windows in the NoCue group, these results demonstrate the presence of reliable memory-related effects in both time windows and justify the more focused ROI analyses, which were followed up by detailed planned comparison inspection of effects.

Firstly, in an across group analysis of time window 1 including data from all five conditions, there were significant condition by ROI ( $F(8,232)=3.08, \epsilon=.79, p<.01$ ) and condition by group ( $F(4,116)=3.13, \epsilon=.92, p=.02$ ) interactions. Focusing on the frontal ROI, there was still a marginally significant condition by group interaction,  $F(4,116)=2.45, \epsilon=1.00, p=.050$ , with the Old/New condition showing the most obvious difference between groups, in line with the main prediction (see Fig. 6).

In the NoCue group, besides a main effect of condition,  $F(4,56)=6.26, \epsilon=1.00, p<.01$ , there was a significant ROI by condition interaction,  $F(8,112)=2.42, \epsilon=.78, p<.05$ . As predicted, contrasts at the midfrontal ROI indicated that both Same and Rearranged differed from New/New, New/Old, and Old/New conditions (see Table 1). There were no differences within these two clusters of conditions (all  $F<1.41, all p>.25$ ). This pattern exactly replicates the Tsivilis et al. (2001) data.

In the Cue group, there was a main effect of condition,  $F(4,60)=17.38, \epsilon=.81, p<.01$ , and a reliable ROI by condition interaction,  $F(8,120)=2.26, \epsilon=.91, p<.05$ . In line with the major hypothesis, planned comparisons revealed that all “old object” conditions (Same, Rearranged, Old/New) differed from New/Old and New/New conditions at the frontal ROI (see

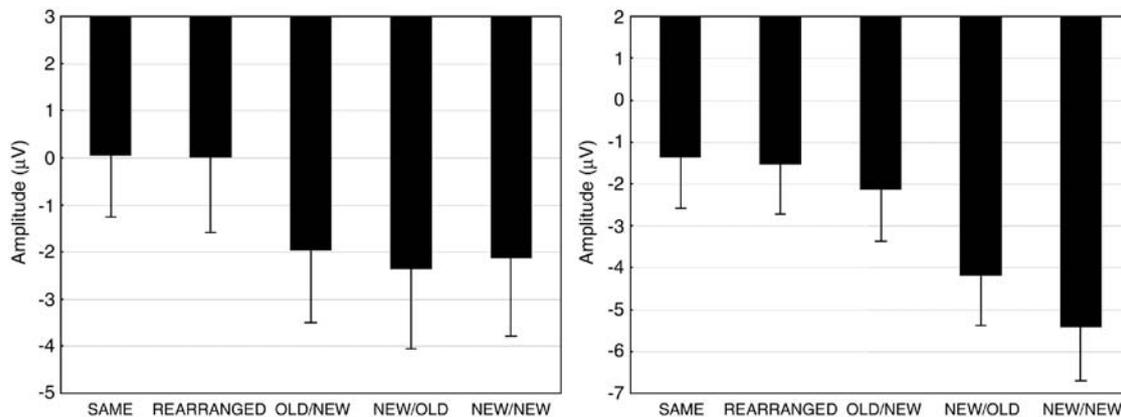


Fig. 6. Mean voltage amplitudes in the NoCue (left) and Cue (right) groups at the frontal ROI in time window 1; vertical bars denote standard errors of the mean.

Table 1  
Planned comparisons at the frontal ROI in time window 1

Contrast	<i>df</i>	<i>F</i>	<i>p</i>
<b>NoCue group</b>			
Same–New/New	1,14	9.84	.0073
Same–New/Old	1,14	9.35	.0085
Same–Old/New	1,14	6.90	.0199
Rearranged–New/New	1,14	13.39	.0026
Rearranged–New/Old	1,14	12.27	.0035
Rearranged–Old/New	1,14	7.50	.0160
<b>Cue group</b>			
Same–New/New	1,15	32.27	<.0001
Same–New/Old	1,15	18.26	.0007
Rearranged–New/New	1,15	21.25	.0003
Rearranged–New/Old	1,15	9.74	.0070
Old/New–New/New	1,15	28.29	.0001
Old/New–New/Old	1,15	33.58	<.0001

Table 1). There were no significant differences within these two clusters of conditions (all  $F < 3.61$ , all  $p > .05$ ).

In an across group analysis of time window 2, condition interacted with group ( $F(4,116) = 3.32$ ,  $\epsilon = .96$ ,  $p = .01$ ) and ROI ( $F(8,232) = 5.42$ ,  $\epsilon = .71$ ,  $p < .001$ ). Focusing on the posterior ROI, the condition by group interaction was still significant,  $F(4,116) = 2.83$ ,  $\epsilon = .92$ ,  $p < .05$ ).

In the NoCue group, besides the main effect of condition,  $F(4,56) = 6.32$ ,  $\epsilon = 1.00$ ,  $p < .01$ , the interaction of condition and ROI was reliable,  $F(8,112) = 3.12$ ,  $\epsilon = .92$ ,  $p < .01$ . Follow-up contrasts indicated that at posterior sites in time window 2, the effects were equivalent to the effects at frontal sites in time window 1. Same and Rearranged differed from Old/New, New/Old, and New/New (see Table 2). There were no significant differences within these two clusters (all  $F < 1.46$ ,  $p > .2$ ).

Analysis of the Cue group data yielded a significant interaction of ROI and condition,  $F(8,120) = 2.97$ ,  $\epsilon = .55$ ,  $p = .02$ ), besides a main effect of condition,  $F(4,60) = 18.82$ ,  $\epsilon = .94$ ,  $p < .001$ ). Planned comparisons at the posterior ROI indicated that Same and Rearranged differed from the remaining conditions, while New/New also differed from New/Old and

Table 2  
Planned comparisons at the posterior ROI in time window 2

Contrast	<i>df</i>	<i>F</i>	<i>p</i>
<b>NoCue group</b>			
Same–New/New	1,14	6.67	.0217
Same–New/Old	1,14	26.16	.0002
Same–Old/New	1,14	11.54	.0043
Rearranged–New/New	1,14	8.59	.0110
Rearranged–New/Old	1,14	26.02	.0002
Rearranged–Old/New	1,14	7.39	.0166
<b>Cue group</b>			
Same–New/New	1,15	31.70	<.0001
Same–New/Old	1,15	30.03	.0001
Same–Old/New	1,15	20.25	.0004
Rearranged–New/New	1,15	25.23	.0002
Rearranged–New/Old	1,15	16.54	.0010
Rearranged–Old/New	1,15	13.00	.0026
New/New–New/Old	1,15	7.02	.0182
New/New–Old/New	1,15	9.82	.0068

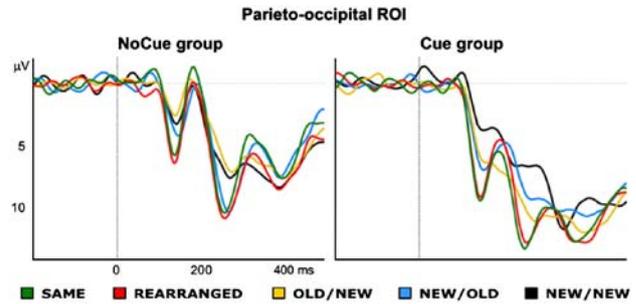


Fig. 7. Stimulus-locked grand average ERPs at right parieto-occipital ROI.

Old/New (see Table 2). Remaining contrasts were nonsignificant ( $F < 1$ ).

Finally, some notice should also be given to an early frontopolar effect observed especially in the NoCue group (New/New less negative from about 100 ms; Tsivilis et al. (2001) had reported a similar effect reversed in polarity), and a late frontal effect in the Cue group. These were analyzed as follows.<sup>4</sup>

Early effects (100–300 ms) were even more apparent at right parieto-occipital sites (see Fig. 7), also in the Cue group. Thus, analyses were focused on frontopolar and right parieto-occipital (electrodes O2, PO4, PO8) ROIs. Time windows 0a and 0b were set to 120–180 ms and 220–300 ms, respectively. Despite a number of significant contrasts in these analyses, we would like to highlight only some aspects concerned with the initial processing of new and old information. These involve across group analyses of Old/New and New/Old conditions, which deliver the vital comparison for the test of different initial attentional foci, and analyses of newly merged superordinate conditions according to the old/new status of objects and/or contexts (details below).

In time window 0a, frontopolar Old/New and New/Old waveforms differed only in the NoCue group ( $F(1,14) = 18.51$ ,  $p < .001$ ), ANOVA yielded a marginally significant condition by group interaction at the frontopolar ROI,  $F(1,29) = 3.81$ ,  $p = .06$ . Merging new superordinate conditions, there were significant complementary patterns of activation for “old context” (Same, Rearranged, New/Old) vs. “new context” (Old/New, New/New) conditions at frontopolar (new more positive) and parieto-occipital (old more positive) ROIs in the NoCue group, both  $F(1,14) > 4.67$ ,  $p < .05$ . In the Cue group, there were likewise complementary patterns contrasting “something-new” (New/New, New/Old, Old/New) vs. “nothing-new” (Same, Rearranged) conditions,  $F(1,15) = 6.79$ ,  $p < .02$ .

In time window 0b, Old/New vs. New/Old analysis at the parieto-occipital ROI again yielded a significant condition by group interaction  $F(4,116) = 4.65$ ,  $\epsilon = .88$ ,  $p < .01$ . Newly merged old vs. new context conditions differed significantly at the parieto-occipital ROI of the NoCue group,  $F(1,14) = 10.26$ ,  $p < .01$ . Likewise, in the Cue group old vs. new object

<sup>4</sup> For reasons of parsimony, only main results will be alluded to here, a full report is available on request from the corresponding author. Reported contrasts were justified by respective ANOVA interactions.

conditions differed,  $F(1,15)=11.31$ ,  $p<.01$ ; the contrast of “something-new” vs. “nothing-new” conditions was also reliable,  $F(1,15)=21.22$ ,  $p<.001$ .

Finally, there was a late frontal fanning effect in the Cue group maximal between 900 and 1100 ms (time window 3). Post-hoc contrasts at the frontal ROI revealed that Same differed reliably from New/New, New/Old, and Old/New; Rearranged also differed from New/New, all  $F(1,15)>9.80$ ,  $p<.007$ .

#### 4. Discussion

Summarizing the main results, all three old object conditions elicited equivalent FN400 effects in the Cue group, whereas in the NoCue group, only Same and Rearranged conditions showed reliable effects. The central finding was thus that the FN400 old–new effect associated with familiarity was present in the Old/New condition of the Cue group, but not the NoCue group. The LPC effect was largest in both groups in Same and Rearranged conditions, in line with behavioral context effects indexing better performance in the Same vs. Old/New condition across groups. Early frontopolar and parieto-occipital effects differentiated old vs. new context conditions in the NoCue group, whereas they were novelty-sensitive in a broader sense in the Cue group.

This study sought to integrate some discrepant findings which have fueled the debate on the extent of contextual influences on familiarity (Bogacz et al., 2001; Cabeza, 2006; Ecker et al., *in press*; Meeter et al., 2005; Tsivilis et al., 2001; Wan et al., 1999; Yonelinas et al., 1999). Our results suggest that the ERP signature of familiarity processing – the FN400 old–new effect – can be influenced by contextual manipulations, thereby replicating a finding of Tsivilis et al. Adding to the existing literature, however, we were successful in demonstrating that this context effect is mediated by salience and can therefore be eliminated if subjects’ attention at test is focused on the to-be-recognized item. In other words, the most likely explanation of the FN400 effects reported in this study (NoCue group) and by Tsivilis et al. is that highly salient backgrounds are perceived and memorized more like objects, and that two old “objects” together elicit a strong familiarity signal — or alternatively, that a novelty signal is produced as soon as one of the stimulus components is new.<sup>5</sup> If, however, the background’s potential to capture attention is counteracted by giving subjects a cue (Cue group), the background is treated by the system as truly contextual – at least in a substantial subset of cases – and the familiarity signal is therefore not affected. The zooming in and out of attention is very likely also captured in the ERPs: the unusual midline topography of the FN400 effect in the Cue group could be due to the influence of

combined bottom-up and top-down attentional processes mediated by anterior–posterior networks (Hahn et al., 2006; Praamstra et al., 2005).

The fact that the familiarity signal occurred earlier in the Cue group as compared to the NoCue group is an indication that the cueing technique we employed did in fact work, although the tendency of a positive-going drift for New/Old items suggests that it did not work in each and every case. Given the above line of reasoning, the seemingly contradictory finding of prolonged reaction times in the Cue group also becomes understandable: although the system supplies a trustworthy familiarity signal quite early, subjects prefer not to rely on a cognitively impenetrable signal and thus strive to integrate contextual information into their decision process as well. Although statistically, counterbalancing precluded any direct inference from background to object old/new status, context may well have served as an affirmative retrieval cue in cases of object status uncertainty. That is, although behavioral performance does indeed show context effects even in the Cue group (and thus there is no differential behavioral effect concerning the Old/New condition across groups), ERP data suggest these are not based on familiarity. The fact that Same and Rearranged waveforms in the Cue group become more positive than Old/New waveforms after about 500 ms may indicate this type of voluntary context check, an alternative explanation being that backgrounds are so salient that they simply cannot be masked out permanently. The late effects in the Cue group, however, also point to controlled post-retrieval checks following contextual integration processes. Methodologically, this pattern of results (i.e., somewhat dissociating behavioral and ERP–FN400 effects) speaks in favor of a dynamic and interactive account of processes leading up to a response, which in our view highlights the potential of ERPs to supply a fine-grained online measure of processing, whereas standard behavioral measures mainly reflect an “end-product” of processing.

With respect to the LPC effect, this study alone does not serve to further clarify its characteristics. The time window by electrode by condition interaction in the Cue group speaks in favor of two distinctive processes — an initial assessment of object familiarity followed up by a more controlled and integrative recollection process indexed by the LPC effect. However, a decision strength account (Finnigan et al., 2002; see also Dunn, 2004) cannot be excluded based on our data: firstly, the two old–new effects do not differ distinctively in their topographies. Although many studies reporting left-lateralized LPC effects have employed verbal materials, the effect was left-lateralized in the original Tsivilis et al. (2001) study, as well. Previous work from our laboratory (Ecker et al., *in press*; Groh-Bordin et al., 2006), however, has indicated that the LPC effect need not show a lateralized distribution under all circumstances, potentially co-depending on the utilized site of reference. Secondly, the equivalent modulation of early and late old–new effects in the NoCue group offers no further support for the assumption of two distinct memory processes. Yet, based on the literature, the most likely interpretation of the LPC effect is in terms of recollection processes (Mecklinger, 2000; Rugg et al., 1998). The fact that in both groups, Same and Rearranged

<sup>5</sup> Strictly speaking, the additive familiarity assumption would predict a graded FN400 effect in the NoCue condition (New/New<New/Old=Old/New<Same=Rearranged). Further research must thus clarify whether the lack of such an effect in both the present and the Tsivilis et al. data is due to a lack of sensitivity of the ERP measure, or due to a novelty signal elicited by a new stimulus component overriding familiarity. Thus, present results do not unequivocally support the association of the FN400 ERP component with “pure” familiarity.

conditions elicited more positive-going waveforms compared to Old/New is in line with the behavioral context effects and the idea that recollection draws on a mnemonic representation that includes contextual information (see Ecker et al., 2004, *in press*). Tsivilis et al. had reported an LPC effect for Old/New repetitions as well; in contrast to their behavioral data, however, Old/New responses in the present NoCue condition were selectively decelerated. This data pattern may imply that the partial mismatch of featural information and accompanying response uncertainty processes precluded the finding of a reliable LPC effect in the Old/New condition of the NoCue group. Also note that the present study differed from the Tsivilis et al. study in terms of study instructions, which were intentional and integrative in the present study. This too may have had a selective influence on recollective processing via stronger integration of context into the mnemonic representation.

The implications of the early frontopolar/parieto-occipital effects remain somewhat unclear, especially as the frontopolar effects reported here are reversed in polarity compared to the effect reported by Tsivilis et al. (2001); see also Curran and Dien (2003) and Speer and Curran (*submitted for publication*). In an fMRI study, Tsivilis et al. (2003) reported extrastriate visual cortex regions as likely sources of the frontopolar ERP effects of their 2001 study, which is highly compatible with our finding of an early bipolar ERP effect (120–180 ms) followed by a parieto-occipital effect (220–300 ms). Besides priming and figure–ground separation processes, a possible interpretation of these effects already adumbrated by Tsivilis et al. (2001) is based on the idea that novelty processing takes place in the system very early, from 100 ms onwards.<sup>6</sup> Due to our cueing technique, context may have been in the focus of attention first in the NoCue group – due to its salience (see also Bar, 2004) –, whereas initial attention tended to be focused on the object in the Cue group. Accordingly, in the NoCue group, there were significant differences between old vs. new context conditions in both early time windows and both ROIs tested. In contrast, effects in the Cue group seem to suggest that initial processing was focused more on the object, although context was still influential; therefore, early effects in the Cue group rather followed an all-old vs. something-new distinction. Likewise, the across group interactions of New/Old and Old/New conditions at both ROIs further corroborate this interpretation. The ERP literature on attentional capture (which is proposed to be reflected in the modulation of a parieto-occipital N2pc component; cf. Luck and Hillyard, 1994; Hickey et al., 2006; Jolicoeur et al., 2006) is in line with this interpretation of the parieto-occipital effects, and the present results are also in accordance with other reports of memory-related modulations of very early visual processing (Busch et al., *submitted for publication*; Herrmann et al., 2004; Kimura et al., 2006). The fact that P1 differences (time window 0a at right parieto-occipital ROI) were obviously greater in the Cue group is in accordance with top-down modulation of attentional and mnemonic

processing, usually reflected in event-related synchronization in the alpha-band (Klimesch et al., 2007). Yet, given the polarity differences across the more memory-related studies, further research must clarify the dynamic interactions of top-down and bottom-up attentional mechanisms (cf. also Crottaz-Herbette and Menon, 2006) with novelty detection at very early stages of processing. Indeed, the cognitive system may assess familiarity/novelty not in a single step, but by an attentionally modulated, iterative approach (Humphreys et al., 1989; Tsivilis et al., 2001).

The main focus of this study was, however, on the early FN400 old–new effect. Assuming that this effect indeed indexes familiarity processing, the combination of our present and earlier data suggests that contextual influences on familiarity are mediated by the characteristics of the context and must be viewed from a dynamic processing perspective. Arbitrary contexts low in salience do not impact on object familiarity despite being retrievable (Ecker et al., *in press*), whereas highly salient contexts can affect the familiarity signal. We suggest that the latter is not a direct contextual influence on object familiarity, but an additional independent familiarity effect of the context stimulus. If the attentional impact of salient contexts is experimentally controlled – as in the present study – this influence is diminished. In other words, if context is treated as context by the system, the familiarity signal is not prone to contextual influences. One note of caution should be added, however, when claiming familiarity is context-free. There is growing evidence that associative recognition can be supported by familiarity as long as the to-be-associated parts of information are similar or easy to unitize, that is, they are from the same modality at least (e.g., associations of faces or face parts, Jäger et al., 2006; Yonelinas et al., 1999 with other potentially relevant dimensions being relative position, size, semantic association (Rhodes and Donaldson, 2007) and repeated study presentations (Speer and Curran, *submitted for publication*). Further, objects were presented in relatively few contexts in this study, whereas in other studies, pairings were unique (e.g., the paired-associate learning task in the strong condition of the Speer and Curran experiments). In terms of *context* memory, we argue that our approach is more valid from an ecological validity point of view, because in the real world, you would typically see many different objects in the same context. Future research should thus more thoroughly investigate the constraints of item unitization, which will then also shed further light on the characteristics of context processing. Concerning the latter, our study demonstrates that salience may be one of the crucial dimensions.

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<sup>6</sup> Note that a recent fMRI study has yielded some evidence for an independent contribution of novelty assessment to recognition memory (Daselaar et al., 2006).

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## References

- Aggleton, J.P., Brown, M.W., 1999. Episodic memory, amnesia, and the hippocampal–anterior thalamic axis. *Behav. Brain Sci.* 22, 425–444.
- Baddeley, A., Vargha-Khadem, F., Mishkin, M., 2001. Preserved recognition in a case of developmental amnesia: implications for the acquisition of semantic memory? *J. Cogn. Neurosci.* 13, 357–369.
- Bar, M., 2004. Visual objects in context. *Nat. Rev. Neurosci.* 5, 617–629.
- Beck, D.M., Kastner, S., 2005. Stimulus context modulates competition in human extrastriate cortex. *Nat. Neurosci.* 8, 1110–1116.
- Bogacz, R., Brown, M.W., Giraud-Carrier, C., 2001. Model of familiarity discrimination in the perirhinal cortex. *J. Comput. Neurosci.* 10, 5–23.
- Brockdorff, N., Lamberts, K., 2000. A feature sampling account of the time course of old–new recognition judgments. *J. Exp. Psychol. Learn.* 26, 77–102.
- Busch, N.A., Groh-Bordin, C., Zimmer, H.D., Herrmann, C.S., submitted for publication. Modes of memory: performance-dependent electrophysiological repetition suppression and recognition enhancement.
- Cabeza, R., 2006. Prefrontal and medial temporal lobe contributions to relational memory in young and older adults. In: Zimmer, H.D., Mecklinger, A., Lindenberger, U. (Eds.), *Handbook of Binding and Memory: Perspectives from Cognitive Neuroscience*. Oxford University Press, Oxford, pp. 315–338.
- Cave, K.R., Kosslyn, S.M., 1989. Varieties of size-specific visual selection. *J. Exp. Psychol. Gen.* 118, 148–164.
- Crottaz-Herbette, S., Menon, V., 2006. Where and when the anterior cingulate cortex modulates attentional response: combined fMRI and ERP evidence. *J. Cogn. Neurosci.* 18, 766–780.
- Curran, T., 2000. Brain potentials of recollection and familiarity. *Mem. Cogn.* 28, 923–938.
- Curran, T., Dien, J., 2003. Differentiating amodal familiarity from modality-specific memory processes: an ERP study. *Psychophysiology* 40, 979–988.
- Curran, T., Tepe, K.L., Piatt, C., 2006. ERP explorations of dual processes in recognition memory. In: Zimmer, H.D., Mecklinger, A., Lindenberger, U. (Eds.), *Handbook of Binding and Memory: Perspectives from Cognitive Neuroscience*. Oxford University Press, Oxford, pp. 467–492.
- Daselaar, S.M., Fleck, M.S., Cabeza, R., 2006. Triple dissociation in the medial temporal lobes: recollection, familiarity, and novelty. *J. Neurophysiol.* 96, 1902–1911.
- Düzel, E., Vargha-Khadem, F., Heinze, H.J., Mishkin, M., 2001. Brain activity evidence for recognition without recollection after early hippocampal damage. *Proc. Natl. Acad. Sci. U. S. A.* 98, 8101–8106.
- Dunn, J., 2004. Remember–know: a matter of confidence. *Psychol. Rev.* 111, 524–542.
- Ecker, U.K.H., Groh-Bordin, C., Zimmer, H.D., 2004. Electrophysiological correlates of specific feature binding in remembering — introducing a neurocognitive model of human memory. In: Mecklinger, A., Zimmer, H.D., Lindenberger, U. (Eds.), *Bound in Memory — Insights from Behavioral and Neuropsychological Studies*. Shaker, Aachen, Germany, pp. 159–193.
- Ecker, U.K.H., Zimmer, H.D., Groh-Bordin, C., in press. Color and context: An ERP study on intrinsic and extrinsic feature binding in episodic memory. *Mem. Cogn.*
- Eldridge, L.L., Knowlton, B.J., Furmanski, C.S., Bookheimer, S.Y., Engel, S.A., 2000. Remembering episodes: a selective role for the hippocampus during retrieval. *Nat. Neurosci.* 3, 1149–1152.
- Finnigan, S., Humphreys, M.S., Dennis, S., Geffen, G., 2002. ERP ‘old/new’ effects: memory strength and decisional factor(s). *Neuropsychologia* 40, 2288–2304.
- Friedman, D., Johnson Jr., R., 2000. Event-related potential (ERP) studies of memory encoding and retrieval: a selective review. *Microsc. Res. Tech.* 51, 6–28.
- Gardiner, J.M., Java, R.I., Richardson-Klavehn, A., 1996. How level of processing really influences awareness in recognition memory. *Can. J. Exp. Psychol.* 50, 114–122.
- Gratton, G., Coles, M.G.H., Donchin, E., 1983. A new method for off-line removal of ocular artifact. *Electroencephalogr. Clin. Neurophysiol.* 55, 468–484.
- Groh-Bordin, C., Zimmer, H.D., Ecker, U.K.H., 2006. Has the butcher on the bus dyed his hair? When color changes modulate ERP correlates of familiarity and recollection. *Neuroimage* 32, 1879–1890.
- Hahn, B., Ross, T.J., Stein, E.A., 2006. Neuroanatomical dissociation between bottom-up and top-down processes of visuospatial attention. *Neuroimage* 32, 842–853.
- Herrmann, C.S., Munk, M.H.J., Engel, A.K., 2004. Cognitive functions of gamma-band activity: memory match and utilization. *Trends Cogn. Sci.* 8, 347–355.
- Hickey, C., McDonald, J.J., Theeuwes, J., 2006. Electrophysiological evidence of the capture of visual attention. *J. Cogn. Neurosci.* 18, 604–613.
- Holm, S., 1979. A simple sequential rejective multiple test procedure. *Scand. J. Statist.* 6, 65–70.
- Humphreys, M.S., Bain, J.D., Pike, R., 1989. Different ways to cue a coherent memory system: a theory for episodic, semantic, and procedural tasks. *Psychol. Rev.* 96, 208–233.
- Jäger, T., Mecklinger, A., Kipp, K.H., 2006. Intra- and inter-item associations doubly dissociate the electrophysiological correlates of familiarity and recollection. *Neuron* 52, 535–545.
- Jolicoeur, P., Sessa, P., Dell’Acqua, R., Robitaille, N., 2006. Attentional control and capture in the attentional blink paradigm: evidence from human electrophysiology. *Eur. J. Cogn. Psychol.* 18, 560–578.
- Kimura, M., Katayama, J., Murohashi, H., 2006. An ERP study of visual change detection: effects of magnitude of spatial frequency changes on the change-related posterior positivity. *Int. J. Psychophysiol.* 62, 14–23.
- Klimesch, W., Sauseng, P., Hanslmayr, S., 2007. EEG alpha oscillations: the inhibition-timing hypothesis. *Brain Res. Rev.* 53, 63–88.
- Lamberts, K., 1998. The time course of categorization. *J. Exp. Psychol. Learn.* 24, 695–711.
- Luck, S.J., Hillyard, S.A., 1994. Electrophysiological correlates of feature analysis during visual search. *Psychophysiology* 31, 291–308.
- Mayes, A.R., Holdstock, J.S., Isaac, C.L., Hunkin, N.M., Roberts, N., 2002. Relative sparing of item recognition memory in a patient with adult-onset damage limited to the hippocampus. *Hippocampus* 12, 325–340.
- Mecklinger, A., 2000. Interfacing mind and brain: a neurocognitive model of recognition memory. *Psychophysiology* 37, 565–582.
- Mecklinger, A., 2006. Electrophysiological measures of familiarity memory. *Clin. EEG Neurosci.* 37, 292–299.
- Meeter, M., Myers, C.E., Gluck, M.A., 2005. Integrating incremental learning and episodic memory models of the hippocampal region. *Psychol. Rev.* 112, 560–585.
- Müller, N.G., Bartelt, O.A., Donner, T.H., Villringer, A., Brandt, S.A., 2003. A physiological correlate of the “zoom lens” of visual attention. *J. Neurosci.* 23, 3561–3565.
- Mumby, D.G., Gaskin, S., Glenn, M.J., Schramek, T.E., Lehmann, H., 2002. Hippocampal damage and exploratory preferences in rats: memory for objects, places, and contexts. *Learn. Memory* 9, 49–57.
- Paul, L., Schyns, P.G., 2003. Attention enhances feature integration. *Vision Res.* 43, 1793–1798.
- Posner, M.I., Snyder, C.R., Davidson, B.J., 1980. Attention and the detection of signals. *J. Exp. Psychol. Gen.* 109, 160–174.
- Praamstra, P., Boutsen, L., Humphreys, G.W., 2005. Frontoparietal control of spatial attention and motor intention in human EEG. *J. Neurophysiol.* 94, 764–774.
- Ranganath, C., Yonelinas, A.P., Cohen, M.X., Dy, C.J., Tom, S.M., D’Esposito, M.D., 2004. Dissociable correlates of recollection and familiarity within the medial temporal lobes. *Neuropsychologia* 42, 2–13.
- Rhodes, S.M., Donaldson, D.I., 2007. Electrophysiological evidence for the influence of unitization on the processes engaged during episodic retrieval: enhancing familiarity based remembering. *Neuropsychologia* 45, 412–424.
- Rugg, M.D., Schloerscheidt, A.M., Mark, R.E., 1998. An electrophysiological comparison of two indices of recollection. *J. Mem. Lang.* 39, 47–69.
- Speer, N.K., Curran, T., submitted for publication. ERP correlates of familiarity and recollection processes in visual associative recognition.

- Srinivas, K., Verfaellie, M., 2000. Orientation effects in amnesics' recognition memory: familiarity-based access to object attributes. *J. Mem. Lang.* 43, 274–290.
- Treisman, A.M., 2006. Object tokens, binding, and visual memory. In: Zimmer, H.D., Mecklinger, A., Lindenberger, U. (Eds.), *Handbook of Binding and Memory: Perspectives from Cognitive Neuroscience*. Oxford University Press, Oxford, pp. 315–338.
- Tsivilis, D., Otten, L.J., Rugg, M.D., 2001. Context effects on the neural correlates of recognition memory: an electrophysiological study. *Neuron* 31, 497–505.
- Tsivilis, D., Otten, L.J., Rugg, M.D., 2003. Repetition effects elicited by objects and their contexts: an fMRI study. *Hum. Brain Mapp.* 19, 145–154.
- Wan, H., Aggleton, J.P., Brown, M.W., 1999. Different contributions of the hippocampus and perirhinal cortex to recognition memory. *J. Neurosci.* 19, 1142–1148.
- Yantis, S., Jonides, J., 1990. Abrupt visual onsets and selective attention: voluntary versus automatic allocation. *J. Exp. Psychol. Human* 16, 121–134.
- Yonelinas, A.P., 2002. The nature of recollection and familiarity: a review of 30 years of research. *J. Mem. Lang.* 46, 441–517.
- Yonelinas, A.P., Kroll, N.E.A., Dobbins, I.G., Soltani, M., 1999. Recognition memory for faces: when familiarity supports associative recognition judgments. *Psychon. Bull. Rev.* 6, 654–661.
- Zimmer, H.D., Mecklinger, A., Lindenberger, U. (Eds.), 2006. *Handbook of Binding and Memory: Perspectives from Cognitive Neuroscience*. Oxford University Press, Oxford.