ERP Evidence for Flexible Adjustment of Retrieval Orientation and Its Influence on Familiarity

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Abstract

■ The assumption was tested that familiarity memory as indexed by a mid-frontal ERP old–new effect is modulated by retrieval orientation. A randomly cued category-based versus exemplar-specific recognition memory test, requiring flexible adjustment of retrieval orientation, was conducted. Results show that the mid-frontal ERP old–new effect is sensitive to the manipulation of study-test congruency—that is, whether the *same* object is repeated identically or a *different* category exemplar is presented at test. Importantly, the effect pattern depends on subjects' retrieval orientation. With a specific orientation, only *same* items elicited an early old–new effect (*same* > *different* = *new*), whereas in the general condition, the old–new effect was graded (*same* > *different* > *new*). This supports the view that both perceptual and conceptual processes can contribute to familiarity memory and demonstrates that the rather automatic process of familiarity is not only data driven but influenced by top–down retrieval orientation, which subjects are able to adjust on a flexible basis. ■

INTRODUCTION

Neuroscientific research has yielded quite convincing evidence that the ability to recognize something or someone as old (i.e., recognition memory) is based on at least two separate processes: familiarity and recollection (cf. Yonelinas, 2002). Recollection is often conceptualized as the basis for vivid episodic remembering. It is assumed to be a rather controlled process that supplies explicit spatio-temporal detail (cf. Herron & Rugg, 2003a). The amount of recollection is thought to vary with the task-relevance of the retrieved features (Ecker, Zimmer, & Groh-Bordin, 2007a) and in particular with the quality and the quantity of retrieved information (Vilberg & Rugg, 2007; Vilberg, Moosavi, & Rugg, 2006; Wilding, 2000). In contrast, the process of familiarity is thought to subserve an undifferentiated feeling of knowing that something has been encountered before (in experimental terms, is "old"). It is widely believed that familiarity quite automatically appraises the "oldness" and/or novelty of the item in the attentional focus (cf. Ecker, Zimmer, Groh-Bordin, & Mecklinger, 2007).

Reasons to consider familiarity automatic include the observation that familiarity (compared with recollection) is a relatively fast process (Öztekin & McElree, 2007; Gronlund & Ratcliff, 1989). Furthermore, divided attention during both encoding and retrieval has less detrimental effects on familiarity than on recollection (Curran, 2004; Troyer & Craik, 2000; Jacoby & Kelley, 1992), although it should be noted that dividing attention may impact on familiarity to some degree (Skinner & Fernandes, 2008; Yonelinas, 2001; for a review, see Yonelinas, 2002), thus somewhat limiting claims of automaticity. Moreover, frontal lobe pathology associated with either age or lesions seems to have relatively small effects on familiarity (Wheeler & Stuss, 2003; Janowsky, Shimamura, & Squire, 1989).

The two processes of familiarity and recollection have been associated with distinct ERP old–new effects and distinct patterns of brain activation (cf. Rugg & Curran, 2007; Aggleton & Brown, 2006; Daselaar, Fleck, & Cabeza, 2006). In particular, a mid-frontal ERP old–new effect occurring around 400 msec poststimulus onset has been linked to familiarity given its insensitivity to depth of processing manipulations (Rugg et al., 1998) and remember/know classifications (Wolk et al., 2006; Curran, 2004; Smith, 1993). Moreover, it has been shown to be present in an amnesic patient with low levels of recollection due to focal hippocampal damage (Düzel, Vargha-Khadem, Heinze, & Mishkin, 2001). A later left-parietal effect has been associated with recollection for a number of reasons, including that it is more pronounced for remember versus know responses (Düzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Smith, 1993), and that it is larger if study context is additionally retrieved (Trott, Friedman, Ritter, & Fabiani, 1997) or for congruently versus incongruently repeated items (Ranganath & Paller, 1999). Also, it is sensitive to depth of processing manipulations (Rugg et al., 1998; Paller & Kutas, 1992).

Familiarity is sometimes seen as part of a semantic memory system (cf. Tulving, 1985) and is thus assumed

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to be only modulated by the match of general information. Yet, recent ERP research has shown that familiarity is sensitive to both conceptual and perceptual study–test overlap (Ecker, Zimmer, & Groh-Bordin, 2007b; Rugg & Curran, 2007; Groh-Bordin, Zimmer, & Ecker, 2006; Schloerscheidt & Rugg, 2004; Curran & Dien, 2003; see also Grove & Wilding, 2009; Srinivas & Verfaellie, 2000). That is, the mid-frontal ERP old–new effect was found to be larger for perceptually identical versus perceptually modified studied items. These perceptual specificity effects seem to be independent of the task relevance of the manipulated feature (Ecker et al., 2007a), which is another reason to believe that familiarity appraisal takes place in a rather automatic, bottom–up fashion (for similar task-independent effects of feature manipulations on behavioral measures, see Zimmer & Steiner, 2003; Engelkamp, Zimmer, & de Vega, 2001; Zimmer, 1995).

Taken together, episodic object familiarity is prevalently viewed as an automatically supplied memory-strength signal graded by the similarity between the memory representation of the study item and the features of the perceived test item. Consequentially, it is a function of the match of a mnemonic representation and the perceptual representation of a probe. It is usually described as yielding an undifferentiated feeling of prior occurrence (e.g., Rugg & Curran, 2007). Our interpretation of the latter aspect is that although the actual signal calculation may be cognitively impenetrable, nevertheless both conceptual and perceptual features of objects may be taken into account. Hence, familiarity may indirectly convey episodic detail about a study episode.[1] We propose that the ratio of perceptual/conceptual appraisal depends on task demands; hence, the calculation of the familiarity signal may be influenced by task-dependent strategies and may thus not be as automatic as previously thought.

For instance, it has been emphasized that to recognize something as old, it is vital for subjects to be in a "retrieval mode." Retrieval mode has been described as a tonically maintained cognitive state biasing the system toward treating external events as retrieval cues (Rugg & Wilding, 2000; Tulving, 1983). The magnitude of ERP old–new effects has been shown to differ according to whether subjects intentionally retrieve information (e.g., Düzel et al., 1999). In a study contrasting implicit and explicit access to memory representations generated under equal conditions, Groh-Bordin, Zimmer, and Mecklinger (2005) reported a familiarity effect in the explicit task only. Thus, familiarity only seems to occur when the test task refers to the context of the study episode (but see Guillem, Bicu, & Debruille, 2001). In this vein, episodic familiarity is not thought to arise automatically—that is, it arises automatically only if one is in the respective retrieval mode.

There is also evidence that under certain conditions, ERP old–new effects may only arise when subjects are in a specific "retrieval orientation." This is understood as a further fractionation of the retrieval mode concept, referring to a highly specific form of processing applied to a retrieval cue (Herron & Wilding, 2004; Rugg & Wilding, 2000). For instance, retrieval orientation would differ for attempts to retrieve phonological versus visual information. In a process-dissociation paradigm, Herron and Rugg (2003a) showed that successful rejection of lures (studied items declared nontargets) need not require recollection: In their study, recollection-related ERP old–new effects were not present for studied nontarget items if specific source information was readily available for targets. This can be seen as an effect of retrieval orientation: The processing of test items as cues for the recollection of target information is fostered, whereas these items become ineffectual as cues for nontarget recollection.[2] Also, Herron and Rugg (2003b) reported that ERP old–new effects were present for nontarget words when items studied as pictures were targets, but not vice versa. This was interpreted as evidence for different retrieval orientations adopted when searching memory for words versus pictures and points to the ability to use retrieval cues highly specifically when adopting a respective retrieval orientation.

Yet, given that familiarity is perceptually specific (see above), the latter asymmetry could also be explained without referring to the concept of retrieval orientation: In the study of Herron and Rugg (2003b), subjects were always tested with words; thus, in the word condition, a target word (also studied as a word) would elicit high perceptual familiarity, whereas a nontarget word (studied as a picture) would not. In the picture condition, a target word (studied as a picture) would not elicit a high amount of perceptual familiarity, whereas a nontarget word (studied as a word) would. Hornberger, Morcom, and Rugg (2004) removed this confounding factor and demonstrated that the study-test similarity of items was a major factor in the generation of previously reported "retrieval orientation" effects. They argued that retrieval orientation effects may reflect attempts to focus processing resources on those test cue attributes that are potentially shared with the targeted mnemonic representations.

One way in which this could be further investigated is to manipulate subjects' retrieval orientation toward retrieving either a specific exemplar or a more general category. Such manipulations have been employed in the literature (Koutstaal, 2006; Werkle-Bergner, Mecklinger, Kray, Meyer, & Düzel, 2005; Ranganath & Paller, 1999, 2000) mainly focusing on the flexibility of control. However, as discussed also by Hornberger et al. (2004), the exact contribution of retrieval orientation to the molding of familiarity/recollection and the respective ERP old–new effects remains to be elucidated, so a thorough investigation of (mid-frontal) old–new effects could shed more light on the question of whether familiarity and the ratio of perceptual/conceptual processing associated with it depend on retrieval orientation beyond basic retrieval mode. This was the aim of the present study.

Given the conceptualization of familiarity as an automatic data-driven process, the finding of a top–down modulation of familiarity would potentially have considerable theoretical impact.

To date, almost all ERP studies investigating retrieval orientation effects have focused on the comparison of correct rejection trials due to the problematic confounding with retrieval success in old item hit trials (e.g., Herron & Wilding, 2006; Dzulkifli & Wilding, 2005; Hornberger et al., 2004). These studies have been successful in discovering direct electrophysiological correlates of retrieval orientation. Yet, they cannot tell us how processing of old items is modulated by retrieval orientation. Additionally, looking only at new items is problematic because new items may be processed differently under different retrieval orientations. For example, with a specific orientation, rejection of a completely new item may involve memory search and decision processes quite different from those involved in the rejection of new objects when adopting a general orientation—when other unstudied exemplars are in fact to be accepted as ''old.'' At least on some trials, the latter will lead to a substantial conflict between a mismatch or novelty signal and the requirement to accept as old unstudied objects that ''happen to belong'' to a studied category, likely leading to differences in the processing of completely new items (e.g., initiating an exhaustive search to double-check if it really is new; Rotello & Heit, 1999; for a related discussion, see Discussion section). As the main goal of this study was to measure the influence of retrieval orientation on well-studied memory retrieval processes and their dependence on perceptual/conceptual information, we consider our approach valid.

Furthermore, research on the flexibility of retrieval orientation mechanisms has not been entirely conclusive. For instance, looking at effects occurring during test probe processing, Johnson and Rugg (2006a) reported that retrieval orientation effects were absent when task demands varied unpredictably, and a similar finding was reported by Herron and Wilding (2006). Likewise, looking at ERPs time locked to instructional task cue presentation, Herron and Wilding (2004) compared two episodic source memory tasks and only found retrieval orientation effects on ''stay'' but not ''switch'' trials. These findings are in line with the initial discussion of the concept in a neuroscientific context by Rugg and Wilding (2000), suggesting that retrieval orientation was a tonically maintained state. Yet, the results of Herron and Wilding (2004) may have been influenced by the fact that the authors also used a third, semantic task, making adequate data separation difficult. This problem was solved in a follow-up study (Herron & Wilding, 2006), which demonstrated flexible adoption of retrieval orientation on cue-locked ERPs, but only on ''switch'' trials, and again, a similar pattern was reported by Johnson and Rugg (2006a). Likewise, Koutstaal (2006)—using a design similar to the one used here—was able to show on a behavioral level that subjects are in fact able to quite flexibly adjust their retrieval orientation on a trial-by-trial basis. Thus, employing a trial-by-trial manipulation of test task, we also aimed to replicate Koutstaal's general finding in an ERP study to contribute to a sharper definition of the retrieval orientation concept.

METHODS

Materials and Design

The experiment took place in a sound- and electromagnetically shielded cabin, and participants sat about 80 cm from the screen. Stimuli were colored photographic images depicting everyday objects, which were presented centrally on a 17-in. flat screen monitor with a maximum expansion of 160 pixels, spanning a visual angle of approximately 2° to 4°. Subjects incidentally studied 160 items (80 natural and 80 artificial). Their task was to categorize the objects as either natural or artificial. Each item was depicted for 2 sec, with a preceding fixation cross (500 msec) and an intertrial interval (ITI) of 1 sec. In the subsequent test phase, subjects' recognition memory was tested with 240 items: 80 studied items that were identically repeated (*Same* condition), 80 items that corresponded to the remaining study items but depicted different exemplars of the same object category (*Different* condition), and 80 items from categories not used in the study phase (*New* condition). The two exemplars of the same category were selected to be identical conceptually but differed in multiple perceptual features such as color, orientation, texture, and perspective (holding constant the ease of identification). No two exemplar versions depicted the identical exemplar, although some versions were more similar than others (a change in perspective makes less difference for round objects, for instance). Figure 1 shows an item sample.

Retrieval orientation was manipulated within subjects by giving inclusion versus exclusion instructions corresponding to a general category-based versus item-specific retrieval orientation (General vs. Specific focus). In the former condition, subjects were instructed to accept as old both objects identical to a study item and different exemplars of studied items (an example was given) and to reject as new only completely new items. In the latter condition, instructions were to accept as old only objects identical to a study item and to reject as new both different exemplars of studied items and completely new items. This manipulation was implemented pseudorandomly on a trial-by-trial basis. Subjects were given a verbal cue (1.5 sec before each trial) on the lower part of the screen indicating the type of test for the upcoming trial. This cue remained on the screen together with the test stimulus; both disappeared when a response was given. Additionally, a fixation cross appeared 500 msec before

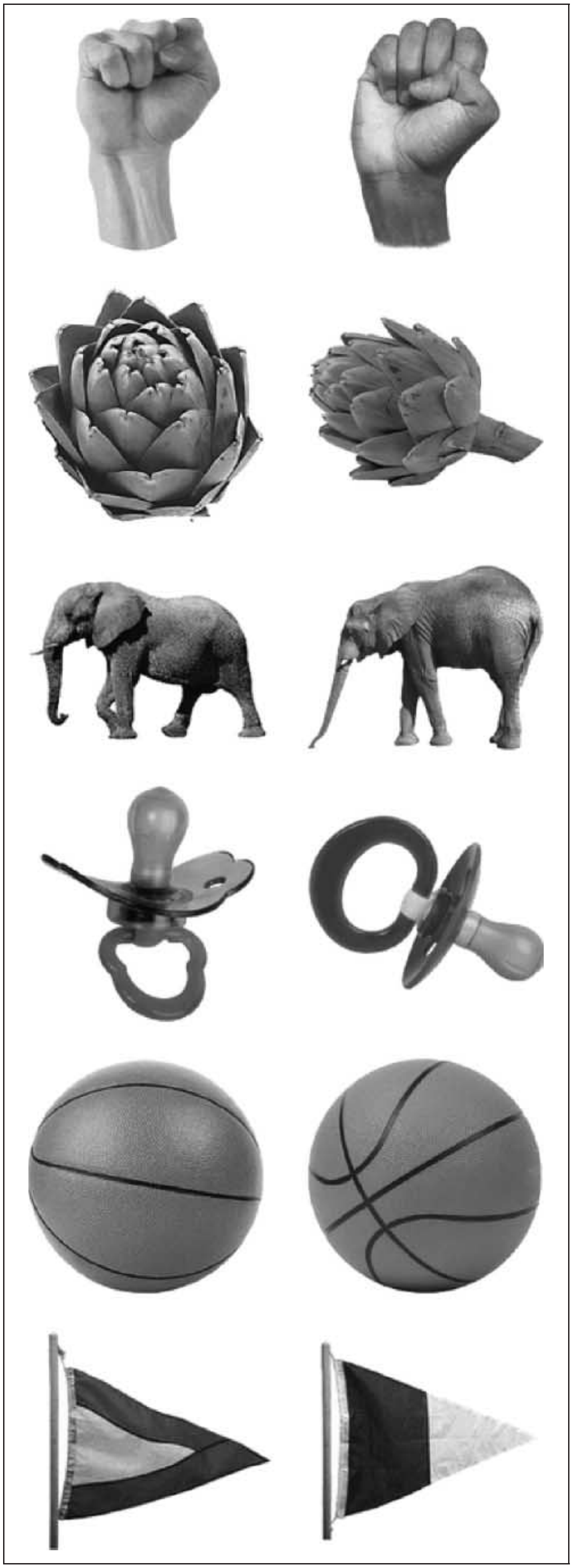

Figure 1. Examples of items used.

test stimulus onset. The factors ''natural/artificial item'' and ''General/specific trial'' were counterbalanced within each experimental condition (Same/Different/New), yielding a cell size of 20. Before the actual test phase, there were 12 practice trials (2 per condition–focus combination). Twenty-four subjects, all students at Saarland University (14 women, mean age = 24.4 years, age range = 20–35 years), participated in this experiment and were paid for their participation. Data of one participant were discarded from analysis because of excessive EEG artifact.

EEG/ERP Methods

The EEG was recorded from 63 Ag/AgCl electrodes arranged according to the extended international 10-20 system (Easycap GmbH, Herrsching-Breitbrunn, Germany). Sampling rate was 250 Hz, and signals were amplified with an AC coupled amplifier (Brain Amp MR, Brain Products, Munich; time constant = 10 sec, analogue low-pass filter = 70 Hz, notch filter = 50 Hz). A left mastoid reference was used, but signals were rereferenced off-line to averaged mastoids. EOG artifacts picked up by four ocular electrodes (two above and below the right eye, and two further electrodes at the outer canthi of both eyes) were corrected off-line (Gratton, Coles, & Donchin, 1983). Before averaging, trials containing artifacts (lowest activity in successive 100 msec intervals $\pm$ 0.5 μV, maximum amplitude in the segment $\pm$ 100 μV, maximum voltage step between two successive sampling points 40 μV, maximum difference between any two sampling points within an epoch 100 μV) were excluded (2.9% of trials). Digital band-pass 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 msec relative to stimulus onset. Analysis was based on trials with correct responses, resulting in the following mean trial numbers per condition: General, New/Same/Different (23/33/29); Specific, New/Same/Different (35/28/27). The minimum number of trials per condition included in a grand average was 16. Following suggestions by Dien and Santuzzi (2005), statistical analyses were performed by means of MANOVAs (using Wilks' lambda F equivalents) on mean voltages in several different time windows (see Results section). For the test ERPs, nine ROIs—allowing for analysis of separate three-level anterior–posterior (AP) and laterality (Lat) factors—were formed by averaging signals from the following electrodes: left-frontal: AF3, F5, and F7; mid-frontal: Fpz, F1, and F2; left-central: C5, CP5, and C7; mid-central: Cz, C3, and C4; left-posterior: P5, P7, and PO3; mid-posterior: Pz, P1, and P2; and the respective right counterparts to left-sided regions and electrodes. Analyses were followed up by planned comparisons, applying Holm's (1979) sequential Bonferroni correction of α levels where applicable.

Hypotheses

Hypotheses were that memory performance should depend on the degree of study-test overlap and response conflict; that is, Same items relative to Different items should be recognized with higher accuracy and lower latency in both groups. Correct rejections were expected to be associated with higher latency and lower accuracy in the General condition, as new items should be harder to reject when at the same time perceptually different exemplars of categories used in the study phase were to be accepted as old.

As far as early frontal ERP old–new effects are concerned, given that familiarity is perceptually specific (see Introduction), we expected that Same exemplars should always elicit a larger effect than Different items. Moreover, we hypothesized that familiarity may be sensitive to retrieval orientation. Thus, we expected the retrieval orientation manipulation to impact differentially on the early frontal old–new effect associated with familiarity. In particular, we assumed that the conceptual/perceptual processing ratio depends on task demands (for instance, see Groh-Bordin et al., 2005; Curran & Cleary, 2003). Therefore, subjects in the Specific focus condition should bias their item processing toward perceptual appraisal, whereas in the General processing condition, conceptual processing should relatively be of more importance. Thus, if familiarity is strategically modulated, the perceptually mismatching Different items should only elicit a reliable frontal old–new effect in the General focus condition.

Concerning later parietal effects associated with recollection, we predicted a graded recollection effect in both focus conditions, given that recollection is assumed to vary with the amount of detailed information retrieved (see Introduction). The amount of retrievable information should obviously be larger for Same items, which were identically repeated and should thus be perfect retrieval cues. Furthermore, we expected the congruency effect (Same vs. Different) to be larger in the Specific focus condition due to the presumed influence of controlled retrieval orientation also on recollection (Herron & Rugg, 2003b; cf. also Rugg & Wilding, 2000).

RESULTS

Behavioral Results

In an ANOVA of *old* responses, which are depicted in Figure 2, a significant interaction emerged between the two factors Focus (General/Specific) and Item condition (Same/Different/New), $F(2,44) = 22.05$, $p < .001$. A post hoc Tukey test indicated that all pairwise differences were significant (all $p < .01$). Concerning the rate of "old" responses to Different items, the two foci differed markedly, as expected [0.74 (correct) vs. 0.32 (incorrect), $p < .001$], demonstrating that participants were able to adjust their retrieval orientation. Comparing *correct* response rates to Different items across foci in a separate analysis, the difference was not significant (0.74 vs. 0.68), $F(1,22) = 3.83$, $p > .05$, showing that the performance level was nearly equivalent. To compare overall memory performance across foci, an analysis was calculated on *Pr* scores (hit rate − false alarm rate; Snodgrass & Corwin, 1988) comparing *Same* and *New* conditions (i.e., the two conditions calling for the same response independent of focus) across foci. Due to the higher false alarm rate in the General condition, memory performance in terms of *Pr* was superior in the Specific condition (0.63 vs. 0.46), $F(1,22) = 19.97$, $p < .001$. Corresponding to the difference in false alarms, an analysis of response bias [$Br = FA / (1 - Pr)$] (Snodgrass & Corwin, 1988) suggested a more liberal criterion in the General compared

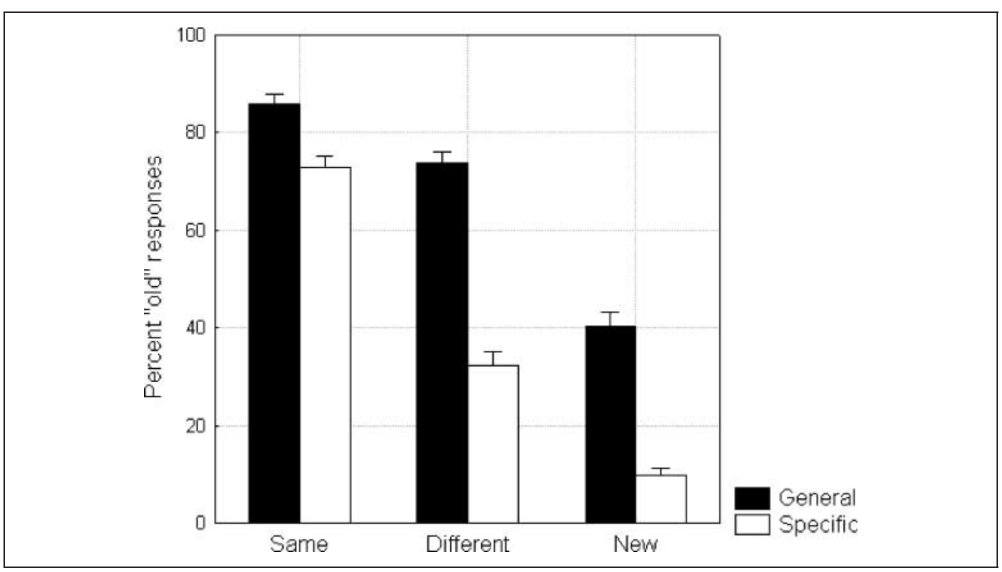

Figure 2. Recognition memory performance (percent "old" responses) across retrieval orientation and study-test conditions. Error bars denote standard errors of the mean. Please note that in the General–Different condition, "old" responses are hits, whereas in the Specific–Different condition, they are false alarms.

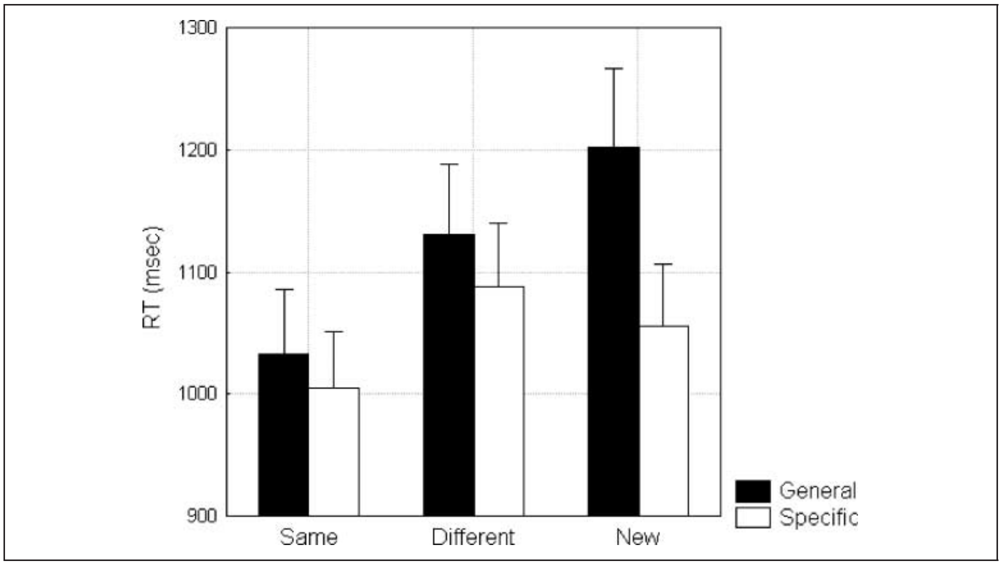

Figure 3. Mean RTs of correct responses (hits and correct rejections) across retrieval orientation and study-test conditions. Error bars denote standard errors of the mean.

with the Specific focus condition (0.73 vs. 0.27), $F(1,22) = 92.18$, $p < .001$.

Turning to RT data of correct responses (Figure 3), subjects responded more quickly in the Specific condition [1050 vs. 1122 msec; $F(1,22) = 28.11$, $p < .001$; interaction with condition significant with $F(2,44) = 10.86$, $p < .001$], and a Tukey test showed that this was particularly so when correctly rejecting new items (1056 vs. 1202 msec, $p < .001$). For both foci, Same repetitions were responded to faster than Different ones (collapsed across foci: 1019 vs. 1110 msec), $F(1,22) = 30.38$, $p < .001$.

ERP Results

ERPs Time Locked to Test Probe Presentation

Grand average ERPs at representative ROIs are shown separately for General and Specific conditions in Figures 4 and 5. In the General condition, there seem to be old–new effects from about 200 msec onward, especially at frontal sites. Yet, this early frontal effect seems to be larger for the Same condition from about 350 msec. A slightly left-lateralized posterior old–new effect is largest from about 500 to 800 msec and is selectively present for Same repetitions. In the Specific condition, old–new

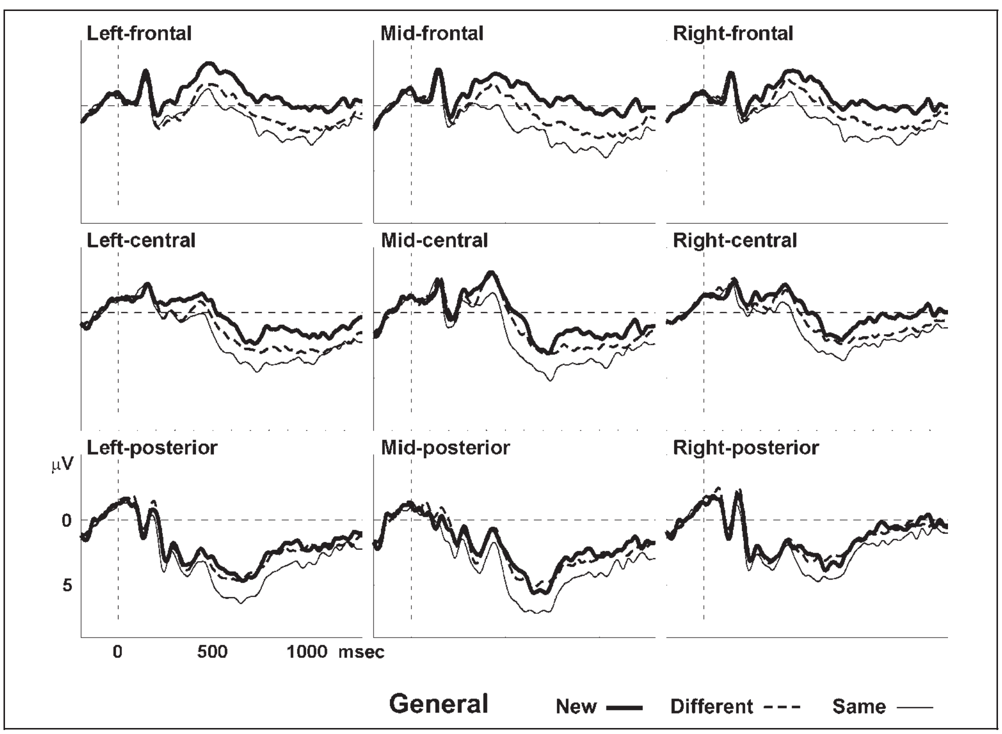

Figure 4. Topographically arranged (ROI) grand average ERP data from the General retrieval orientation condition time locked to test probe presentation.

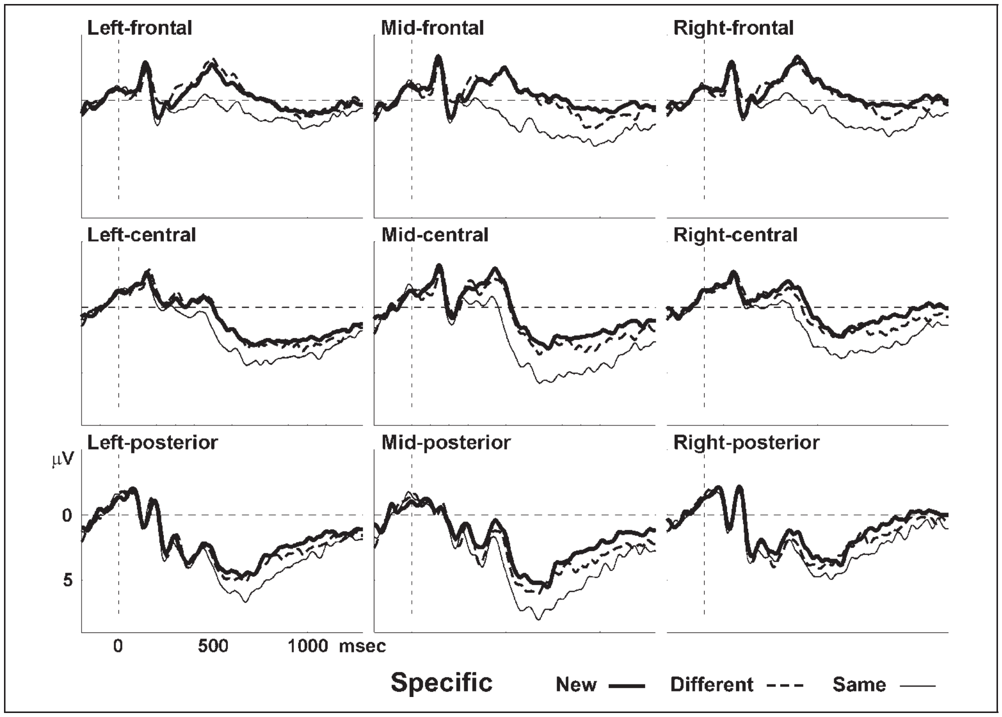

Figure 5. Topographically arranged (ROI) grand average ERP data from the specific retrieval orientation condition time locked to test probe presentation.

effects are restricted to Same items and are visible from about 300 msec, again with an anterior maximum. A more posterior component arises at around 500 msec and also seems slightly left lateralized. Reflecting these patterns, time windows were set to 200–350, 350–500, and 500–800 msec.

In Time window 1 (200–350 msec), an AP × Lat × Focus (General/Specific) × Condition (New/Same/Different) MANOVA yielded an AP × Focus × Condition interaction, $F(4,19) = 3.85$, $p = .019$. In the specific condition, Same and Different waveforms differed at frontal sites, and there was a reversed old–new effect for Different items at the left frontal ROI. In the General condition, there was an equivalent old–new effect for both old conditions at the left- and mid-frontal ROIs (see Table 1).

In Time window 2 (350–500 msec), an AP × Lat × Focus (General/Specific) × Condition (New/Same/Different) analysis yielded significant three-way interactions of Focus, Condition, and both AP and Lat, both Fs$(4,19) > 3.42$, ps $< .03$. Taken together, in the Specific condition, there was a frontal old–new effect only for Same items (Same > Different = New). In contrast, in the General condition, there was an old–new effect for both old conditions, and additionally there was also a significant difference between Same and Different items, reflecting the fact that the frontal old–new effect was graded (Same > Different > New; see Table 2). This difference between foci was reflected in a significant interaction contrast of focus and condition (Same/Different) at the mid-frontal ROI, $F(1,22) = 6.27$, $p = .02$.

Table 1. Follow-up Contrasts at Left- and Mid-frontal ROIs, Time Window 1

Contrast	*df*	*F*	*p*
Specific Focus—Left-frontal ROI			
New–Same	1,22	2.02	>.10
New–Different	1,22	5.98	.0230*
Same–Different	1,22	10.42	.0039*
Specific Focus—Mid-frontal ROI			
New–Same	1,22	1.55	>.10
New–Different	1,22	3.00	.10
Same–Different	1,22	7.87	.0103*
General Focus—Left-frontal ROI			
New–Same	1,22	8.07	.0095*
New–Different	1,22	21.84	.0001*
Same–Different	1,22	<1	
General Focus—Mid-frontal ROI			
New–Same	1,22	5.82	.0246*
New–Different	1,22	6.91	.0153*
Same–Different	1,22	<1	

*Indicates significant p values following α correction.

Table 2. Follow-up Contrasts at Mid-frontal ROI, Time Window 2

Contrast	*df*	*F*	*p*
Specific Focus—Mid-frontal ROI			
New–Same	1,22	32.39	<.0001*
New–Different	1,22	<1	
Same–Different	1,22	23.68	.0001*
General Focus—Mid-frontal ROI			
New–Same	1,22	25.22	.0001*
New–Different	1,22	4.41	.0475*
Same–Different	1,22	12.59	.0018*

*Indicates significant p values following α correction.

In an AP × Lat × Focus (General/Specific) × Condition (New/Same/Different) MANOVA on Time window 3 (500–800 msec) data, the only significant interaction was between Lat and Condition, $F(4,19) = 3.31$, $p = .03$, most likely reflecting the fact that overall old–new effects were slightly left lateralized. For the sake of completeness, the apparent old–new effect for Same repetitions was confirmed in a post hoc contrast at the left posterior ROI, as this is where recollection-related ERP activity is typically found. As there were no interactions involving the focus factor, the contrast was calculated on data collapsed across specific/general orientations. Same differed from both New and Different, both Fs(1,22) > 10.86, ps < .004, and there was no difference between the two latter conditions ($F < 1$).

ERPs Time Locked to Test Cue Presentation

To further test the idea that the described memory effects are in fact related to differential processing following trialwise presentation of cues (i.e., establishment of different retrieval orientations set off by these cues), ERPs time locked to cue onset were additionally examined. For this purpose, all trials were classified according to the presented cue, resulting in the two cue conditions General and Specific. The mean number of trials contributing to the grand averages was 112 in both conditions. Analysis methods were equivalent to the analysis of memory ERPs. Specific ERPs seemed to be more positive from approximately 200 to 350 msec post cue onset, mainly at frontopolar electrodes. In contrast, the reverse pattern was apparent at occipital electrodes. Furthermore, Specific ERPs at occipital electrodes continued to be more negative until about 750 msec. ERPs from selected electrodes are shown in Figure 6.

We tested these effects using a 2 × 3 grid of single electrodes (Fp/O 1/z/2), resulting in a three-level factor Lat and two 2-level factors AP and Condition. MANOVA on 200–350 msec data revealed a significant Condition × AP × Lat interaction, $F(2,21) = 5.19$, $p = .015$. Follow-up contrasts indicated a highly significant difference at the left occipital electrode, $F(1,22) = 9.42$, $p = .006$ (alongside marginally significant differences at the other two occipital and the right frontopolar electrode), Fs(1,22) > 3.07, ps < .09. A further analysis on occipital (O1/z/2) data from 350 to 750 msec revealed a marginally significant Condition × Lat interaction, $F(2,21) = 3.39$, $p = .053$, with follow-up contrasts showing that conditions differed reliably at both left and right occipital electrodes, Fs(1,22) = 4.71 and 9.43, ps = .04 and .006, respectively.

DISCUSSION

The aim of this experiment was twofold. Primarily, we wanted to test whether familiarity (as measured by the associated ERP old–new effect) is modulated by retrieval orientation (general vs. specific) beyond basic retrieval

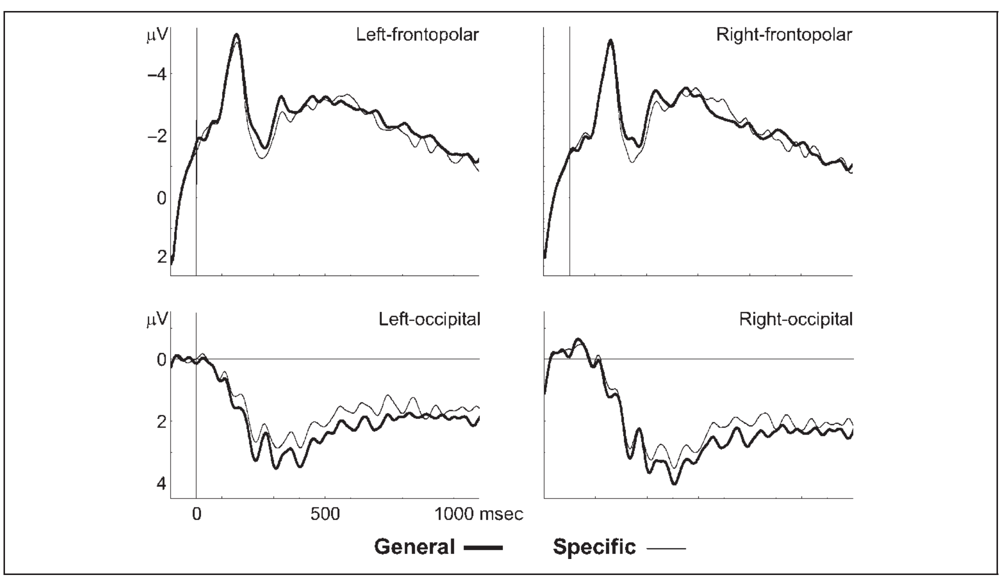

Figure 6. Grand average ERP data from selected electrodes time locked to General and Specific test cue presentation.

mode. More precisely, we hypothesized that a specific retrieval orientation would augment the impact of perceptual features on memory, whereas the impact of conceptual features would be stronger with a general retrieval orientation. Second, we aimed at replicating Koutstaal's (2006) finding that subjects can flexibly adjust their retrieval orientation on a trial-by-trial basis, in particular as the original discussion of the term by Rugg and Wilding (2000) suggested it may be tonically maintained. If participants are able to adjust their retrieval orientation instantly, we should expect a modulation of ERP old–new effects on a trial-by-trial basis. The main results are as follows.

As far as behavioral memory performance is concerned, the data pattern of the Koutstaal (2006) study was approximately replicated. Subjects were capable of adjusting their retrieval orientation on a trial-by-trial basis, performing well in both the two randomly interspersed tasks. This suggests that retrieval orientation can be adapted flexibly to task demands. This was supported by two ERP results. The first is a pure orientation effect. Shortly after cue presentation, the amplitudes at occipital sites are modified by the type of cue (Specific vs. General). However, this effect is weak and it needs further replication especially given the fact that electrodes and time windows for the present cue-locked ERP analysis were selected post hoc and differ somewhat from previous findings (see especially Herron & Wilding, 2006). On the other hand, the topography of this effect is compatible with the idea that retrieval orientation influences weighting of perceptual features. A likely mechanism of this process is biased competition (Desimone & Duncan, 1995), which is very likely associated with top–down regulations of perceptual processing networks. Another strong argument in favor of a trial-by-trial regulation of retrieval orientation is the task-specific change of the early frontal old–new effect to targets that we more thoroughly discuss below. These findings suggest that retrieval orientation is not exclusively a tonically maintained state. It may be that both slowly and quickly evolving facets of retrieval orientation exist (there may be task set reconfigurations preceding the adoption of stable retrieval orientation; cf. Herron & Wilding, 2006; Johnson & Rugg, 2006a), and it could depend on task demands or participants' cognitive flexibility whether retrieval is flexible or tonic. This should be addressed by future research.

Most importantly for present purposes, however, memory ERP results suggest that episodic familiarity is directly influenced by retrieval orientation. In the Specific focus condition, only identically repeated items elicited a mid-frontal old–new effect (Same > Different = New) despite equivalent performance rates for the two classes of old items. In contrast, the effect was graded (Same > Different > New) in the General focus condition. This pattern of ERP results points to the ability of subjects to direct their retrieval attempts to specific perceptual exemplar information or to give more weight to general (conceptual) category information, depending on task demands. This finding is obviously in line with proposals by Johnson and Rugg (2006b) and Hornberger et al. (2004) that retrieval orientation is associated with focusing retrieval processing resources on cue aspects potentially shared with the targeted memory representation. However, this is to our knowledge the first ERP study to demonstrate such an impact of retrieval demands on familiarity, a process widely believed to be rather automatic. Hence, our results suggest that beyond familiarity not being fully automatic inasmuch as it prerequires subjects to be in a tonic retrieval mode (see Introduction), familiarity is also partially dependent on subjects' strategic retrieval orientation.

This finding of a top–down modulation of familiarity is broadly in line with recent fMRI findings by Dudukovic and Wagner (2007), who reported that MTL activity associated with novelty detection is not obligatory but can be modulated by the goal-directed allocation of attention. Ecker (2007) has argued that the frontal ERP old–new effect may in fact reflect the outcome of an iterative cascade of subprocesses assessing stimulus novelty, recency, and familiarity (see also Ecker et al., 2007; Tsivilis, Otten, & Rugg, 2001). Thus, instead of viewing stimulus familiarity as a unitary process, it can also be considered an amalgamation of subcomponents that are neurophysiologically distinct (cf. Daselaar et al., 2006; Xiang & Brown, 1998) but can functionally and phenomenologically be seen as two sides of the same medal. In a similar vein, Rugg and Curran (2007) have suggested that the ERP effect associated with familiarity originates from the PFC, where the outcome of the abovementioned subprocesses may be utilized in an integrative manner for further processing and/or the control of action. Likewise, Aggleton and Brown (2006) have suggested that neuronal circuits calculating familiarity/novelty via anti-Hebbian learning should be distinct from those subserving actual feature extraction and stimulus classification. Thus, taken together, the mid-frontal old–new effect at around 400 msec likely reflects the (conscious) outcome of a series of more automatic (and cognitively impenetrable) subprocesses, and it may in fact be this process "downstream" of actual familiarity processing (cf. Tsivilis et al., 2001) that is modulated by task demands.

There is, however, a somewhat different way to look at the observed data pattern. Possibly, subjects maintained a specific focus throughout the experiment and only adjusted their response criterion, adopting a more liberal criterion in the General focus condition. Previous research has suggested that familiarity (compared with recollection) is particularly affected by criterion placement (cf. Yonelinas, 2002). The apparent response bias difference between conditions could be taken as evidence for this. Yet, we do not believe this explanation. First, it is all but clear that the different rates of false alarms for new items are a consequence of a difference in bias. With a specific focus, recognizing that a specific exemplar was not seen before (Different or New items) is sufficient to reject the item. In contrast, with a general focus, this is not possible because a new exemplar from an old category (Different items) has to be accepted as old. As a consequence, all perceptually different new items are potential candidates for an ''old'' response in the General focus condition, and this is not true of the Specific focus condition. This will change false alarm rates even if there is no shift of the criterion (e.g., because guessing processes will operate on more items in the general condition). Second, it is unclear whether bias can actually be changed on a trial-by-trial basis. Sometimes evidence for a flexible adjustment of criterion is found (Rhodes & Jacoby, 2007; Heit, Brockdorff, & Lamberts, 2003), but sometimes it is not (e.g., Morrell, Gaitan, & Wixted, 2002; Stretch & Wixted, 1998), and at other times it may have been manipulations of memory strength and not differences in bias that were effective (Singer & Wixted, 2006; Dobbins & Kroll, 2005), which is not the case in the present study. Third, a simple shift in response criterion should in fact affect both Same hit and correct rejection waveforms in the same way. Correspondingly, Azimian-Faridani and Wilding (2006) have reported no influence of response criterion setting on the magnitude of the mid-frontal ERP old–new effect associated with familiarity. What they did find was a positive shift of both hit and correct rejection waveforms associated with a conservative response criterion. In the present case, however, mid-frontal Same and New ERPs of the Specific focus condition of Time window 2 are not reliably more positive going than respective ERPs of the General condition ($F < 1$), which suggests that an interpretation in terms of response criterion setting cannot account for the complete data pattern in a straightforward manner.[3] Although beyond the scope of the present article, it should also be noted that the present results are entirely consistent with so-called global match models of recognition memory (e.g., Dennis & Humphreys, 2001; Gillund & Shiffrin, 1984), which use the term familiarity to refer to the strength of evidence of an item in response to a context-specific retrieval cue (and cue construction could be perceptually or conceptually biased; for a more thorough review of this issue, see Ecker, 2007). Further results are discussed in the following paragraphs.

In terms of RTs, Same items produced the lowest latencies in both conditions, as expected. This reflects a congruency effect because Same items matched in both perceptual and conceptual information, whereas Different items only matched in conceptual information. Different items, therefore, elicited some degree of response conflict due to partially mismatching information in both foci (i.e., rejecting conceptually identical items in the Specific condition and accepting perceptually different items in the General condition). The longest RTs were observed for New items in the General condition, and there is a significant difference between the two retrieval orientations. This is likely due to conflict monitoring processes peculiar to the General condition, which as discussed above demanded subjects to accept as old a large number of not-yet-encountered items. Thus, subjects seemingly double checked whether a new item was really new or just a different exemplar of a category used at study. Although it was not formally tested here for reasons of conciseness, the late frontal ERP old–new effects (tending to be broader and larger in the General condition; see also Ranganath & Paller, 1999) may be associated with these types of conflict monitoring and resolution. Taken together, the behavioral congruency effects are in line with the assumption that conceptual and perceptual processes both contribute to recognition memory performance.

Turning to ERPs, beyond the impact of retrieval orientation on the frontal old–new effect associated with familiarity, there are other interesting aspects of the data. In particular, in the General focus condition, the frontal old–new effect seems to consist of two subcomponents: An early (200–350 msec) old–new effect of equivalent magnitude for both old conditions (Same = Different > New) preceded the graded effect discussed above (350–500 msec). This pattern suggest that not only both perceptual and conceptual subprocesses contribute to familiarity but also the conceptual processing part of familiarity may come into effect earlier than the perceptual part, given certain constraints in terms of task demands. That is, task demands modify the weighting of conceptual and perceptual features and thereby also the timing of the evaluation of these features. This view is in accordance with the above conceptualization of familiarity as the outcome of a dynamic cascade of subprocesses, which was initially motivated by other reports of anterior old–new effects occurring before 300 msec (see especially Tsivilis et al., 2001, who found a 100- to 300-msec effect contrasting completely new stimulus displays and displays containing an old component and concluded that the later mid-frontal old–new effect may in fact index a process ''downstream'' of familiarity; see also Ecker et al., 2007; Duarte, Ranganath, Winward, Hayward, & Knight, 2004).

As an aside, the early conceptual old–new effect seems to be slightly left lateralized,[4] so alternatively this effect preceding the ''standard'' mid-frontal effect may be an electrophysiological signature of conceptual implicit memory (Paller, Voss, & Boehm, 2007; Yovel & Paller, 2004). Although keeping in mind the difficulties in mapping ERP effects directly onto underlying cortical activity, note that repetition suppression associated with conceptual priming has been linked to left-frontal brain regions (Meister, Buelte, Sparing, & Boroojerdi, 2007; Buckner, Koutstaal, Schacter, & Rosen, 2000). Initially, one would think that if this left-frontal effect reflected implicit memory processes, it should be apparent in both General and Specific conditions of the present study. However, Yovel and Paller (2004) have suggested that the (mid-frontal) effect reflects verbally mediated conceptual priming. Given the task differences discussed above, it seems plausible that participants only profited substantially from naming test stimuli in the General condition. Hence, with a general, category-based retrieval orientation, the left-frontal effect could reflect the greater ease of naming a repeated item category. However, this cannot be the only source of the later mid-frontal old–new effect (as argued by Yovel & Paller, 2004) because this is affected by perceptual differences of conceptually identical Same and Different items and also occurs when naming is impossible or prevented (Groh-Bordin et al., 2006; but see Voss & Paller, 2007). Note also that the present 350- to 500-msec old–new effect for Different items in the General condition is slightly left lateralized as well, which could point to an association between conceptual familiarity subprocesses and left lateralization. Clearly, future research is necessary to investigate these potential subcomponents of the old–new effect more directly.

Finally, in both focus conditions, posterior old–new effects—usually associated with recollection—were confined to Same repetitions. This is in line with the notion that recollection supplies detailed information regarding the study episode and varies with the amount of retrieved feature information (see Introduction). Yet, we had expected a larger congruency (Same vs. Different) effect in the Specific focus condition compared with the General focus condition in line with previous research (e.g., Ecker et al., 2007a; Curran & Cleary, 2003; Curran & Dien, 2003). In particular, it is somewhat unclear why there was no parietal old–new effect for Different items of the General focus condition (for a similar pattern, see Stenberg, Johansson, & Rosén, 2006). Given that recollection is an effortful and controllable process (cf. Bergström, Velmans, de Fockert, & Richardson-Klavehn, 2007; Herron & Rugg, 2003a), however, and in light of the graded (and therefore in many cases equivocal) familiarity signal in the General condition, subjects may have used the recollection signal for an unequivocal initial classification of ''same'' and ''not-same'' items, and thus recollection only occurred strongly if triggered bottom–up by a perceptually matching cue. Then subjects may have relied on post-recollection evaluation processes (reflected in frontal activity) to distinguish between Different and New items (see also above discussion of longer latencies for New items in the General condition). Yet, as this is a post hoc account, future research should aim to further elucidate the constraints of retrieval orientation effects on recollective processing.

Acknowledgments

This research was supported by a grant (Zi 308/4) to H. D. Zimmer from the Deutsche Forschungsgemeinschaft (DFG) within the Research Group FOR 448 ''Binding: Functional Architecture, Neural Correlates, and Ontogeny.'' We thank Anna Arend and Kirstin Bergström for assistance.

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Notes

1. As a side note, this is a feature that has been demanded of computational dual-process models to achieve similar good data fits as compared with formal global match models (see Heathcote, Raymond, & Dunn, 2006).
2. Note that the authors preferred an alternative interpretation of their results in terms of an attentional bias.
3. It should be noted that most recognition memory studies manipulating response criterion have done this in a rather subtle way, for instance by manipulating the base rate of old and new test items (Rhodes & Jacoby, 2007; Heit et al., 2003; Estes & Maddox, 1995) or by leading subjects to believe this to be the case (Verfaellie, Giovanello, & Keane, 2001; Hirshman & Henzler, 1998; Strack & Förster, 1995), whereas in the present case, the adoption of different retrieval orientations or response criteria was explicitly determined by instructions, making it a clear instance of top–down modulation in either case, so interpretations may not be mutually exclusive.
4. It should be noted at this stage that this effect pattern—an early and slightly left-lateralized old–new effect sensitive only to conceptual overlap followed by a perceptually specific mid-frontal old–new effect—replicates a finding by Groh-Bordin, Zimmer, and Ecker (submitted) in a very similar task.

REFERENCES

Aggleton, J. P., & Brown, M. W. (2006). Interleaving brain systems for episodic and recognition memory. *Trends in Cognitive Sciences, 10,* 455–463.

Azimian-Faridani, N., & Wilding, E. L. (2006). The influence of criterion shifts on electrophysiological correlates of recognition memory. *Journal of Cognitive Neuroscience, 18,* 1075–1086.

Bergström, Z. M., Velmans, M., de Fockert, J., & Richardson-Klavehn, A. (2007). ERP evidence for successful voluntary avoidance of conscious recollection. *Brain Research, 1151,* 119–133.

Buckner, R. L., Koutstaal, W., Schacter, D. L., & Rosen, B. R. (2000). Functional MRI evidence for a role of frontal and inferior temporal cortex in amodal components of priming. *Brain, 123,* 620–640.

Curran, T. (2004). Effects of attention and confidence on the hypothesized ERP correlates of recollection and familiarity. *Neuropsychologia, 42,* 1088–1106.

Curran, T., & Cleary, A. M. (2003). Using ERPs to dissociate recollection from familiarity in picture recognition. *Cognitive Brain Research, 15,* 191–205.

Curran, T., & Dien, J. (2003). Differentiating amodal familiarity from modality-specific memory processes: An ERP study. *Psychophysiology, 40,* 979–988.

Daselaar, S. M., Fleck, M. S., & Cabeza, R. (2006). Triple dissociation in the medial temporal lobes: Recollection, familiarity, and novelty. *Journal of Neurophysiology, 96,* 1902–1911.

Dennis, S., & Humphreys, M. S. (2001). A context noise model of episodic word recognition. *Psychological Review, 108,* 452–478.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18,* 193–222.
Dien, J., & Santuzzi, A. M. (2005). Application of repeated measures ANOVA to high-density ERP datasets: A review and tutorial. In T. C. Handy (Ed.), *Event-related potentials: A methods handbook* (pp. 33–56). Cambridge, MA: MIT Press.
Dobbins, I. J., & Kroll, N. E. A. (2005). Distinctiveness and the recognition mirror effect: Evidence for an item-based criterion placement heuristic. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31,* 1186–1198.
Duarte, A., Ranganath, C., Winward, L., Hayward, D., & Knight, R. T. (2004). Dissociable neural correlates for familiarity and recollection during the encoding and retrieval of pictures. *Cognitive Brain Research, 18,* 255–272.
Dudukovic, N. M., & Wagner, A. D. (2007). Goal-dependent modulation of declarative memory: Neural correlates of temporal recency decisions and novelty detection. *Neuropsychologia, 45,* 2608–2620.
Düzel, E., Cabeza, R., Picton, T. W., Yonelinas, A. P., Scheich, H., Heinze, H. J., et al. (1999). Task-related and item-related brain processes of memory retrieval. *Proceedings of the National Academy of Sciences, U.S.A., 96,* 1794–1799.
Düzel, E., Vargha-Khadem, F., Heinze, H. J., & Mishkin, M. (2001). Brain activity evidence for recognition without recollection after early hippocampal damage. *Proceedings of the National Academy of Sciences, U.S.A., 98,* 8101–8106.
Düzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H. J., & Tulving, E. (1997). Event-related brain potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Sciences, U.S.A., 94,* 5973–5978.
Dzulkifli, M. A., & Wilding, E. L. (2005). Electrophysiological indices of strategic episodic retrieval processing. *Neuropsychologia, 43,* 1152–1162.
Ecker, U. K. H. (2007). *Objects in context. The neurocognitive representation, binding, and processing of object and context features in recognition memory—An electrophysiological approach*. Saarbrücken, Germany: VDM.
Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007a). Colour and context: An ERP study on intrinsic and extrinsic feature binding in episodic memory. *Memory & Cognition, 35,* 1483–1501.
Ecker, U. K. H., Zimmer, H. D., & Groh-Bordin, C. (2007b). The influence of object and background colour manipulations on the electrophysiological indices of recognition memory. *Brain Research, 1185,* 221–230.
Ecker, U. K. H., Zimmer, H. D., Groh-Bordin, C., & Mecklinger, A. (2007). Context effects on familiarity are familiarity effects of context—An electrophysiological study. *International Journal of Psychophysiology, 64,* 146–156.
Engelkamp, J., Zimmer, H. D., & de Vega, M. (2001). Pictures and words in memory: The role of visual-imaginal information. In M. Denis, C. Cornoldi, R. H. Logie, M. de Vega, & J. Engelkamp (Eds.), *Imagery, language and visuo-spatial thinking* (pp. 59–80). Hove, UK: Psychology Press.
Estes, W. K., & Maddox, W. T. (1995). Interactions of stimulus attributes, base rates, and feedback in recognition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 1075–1095.
Gillund, G., & Shiffrin, R. M. (1984). A retrieval model for both recognition and recall. *Psychological Review, 91,* 1–67.
Gratton, G., Coles, M. G. H., & Donchin, E. (1983). A new method for off-line removal of ocular artifact. *Electroencephalography and Clinical Neurophysiology, 55,* 468–484.
Groh-Bordin, C., Zimmer, H. D., & Ecker, U. K. H. (2006). Has the butcher on the bus dyed his hair? When colour changes modulate ERP correlates of familiarity and recollection. *Neuroimage, 32,* 1879–1890.
Groh-Bordin, C., Zimmer, H. D., & Ecker, U. K. H. (submitted). A rose is not a rose is not a rose: Electrophysiological correlates of exemplar-specific processes in implicit and explicit memory.
Groh-Bordin, C., Zimmer, H. D., & Mecklinger, A. (2005). Feature binding in perceptual priming and in episodic object recognition: Evidence from event-related brain potentials. *Cognitive Brain Research, 24,* 556–567.
Gronlund, S. D., & Ratcliff, R. (1989). Time course of item and associative information: Implications for global memory models. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 846–858.
Grove, K. L., & Wilding, E. L. (2009). Retrieval processes supporting judgments of recency. *Journal of Cognitive Neuroscience, 21,* 461–473.
Guillem, F., Bicu, M., & Debruille, J. B. (2001). Dissociating memory processes involved in direct and indirect tests with ERPs to unfamiliar faces. *Cognitive Brain Research, 11,* 113–125.
Heathcote, A., Raymond, F., & Dunn, J. (2006). Recollection and familiarity in recognition memory: Evidence from ROC curves. *Journal of Memory and Language, 55,* 495–514.
Heit, E., Brockdorff, N., & Lamberts, K. (2003). Adaptive changes of response criterion in recognition memory. *Psychonomic Bulletin and Review, 10,* 718–723.
Herron, J. E., & Rugg, M. D. (2003a). Strategic influences on recollection in the exclusion task: Electrophysiological evidence. *Psychonomic Bulletin & Review, 10,* 703–710.
Herron, J. E., & Rugg, M. D. (2003b). Retrieval orientation and the control of recollection. *Journal of Cognitive Neuroscience, 15,* 843–854.
Herron, J. E., & Wilding, E. L. (2004). An electrophysiological dissociation of retrieval mode and retrieval orientation. *Neuroimage, 22,* 1554–1562.
Herron, J. E., & Wilding, E. L. (2006). Neural correlates of control processes engaged before and during recovery of information from episodic memory. *Neuroimage, 30,* 634–644.
Hirshman, E., & Henzler, A. (1998). The role of decision processes in conscious recollection. *Psychological Science, 9,* 61–65.
Holm, S. (1979). A simple sequential rejective multiple test procedure. *Scandinavian Journal of Statistics, 6,* 65–70.
Hornberger, M., Morcom, A. M., & Rugg, M. D. (2004). Neural correlates of retrieval orientation: Effects of study-test similarity. *Journal of Cognitive Neuroscience, 16,* 1196–1210.
Jacoby, L. L., & Kelley, C. M. (1992). Unconscious influences of memory: Dissociations and automaticity. In A. D. Milner & M. D. Rugg (Eds.), *The neuropsychology of consciousness* (pp. 201–233). San Diego, CA: Academic Press.
Janowsky, J. S., Shimamura, A. P., & Squire, L. R. (1989). Source memory impairment in patients with frontal lobe lesions. *Neuropsychologia, 27,* 1043–1056.
Johnson, J. D., & Rugg, M. D. (2006a). Electrophysiological correlates of retrieval processing: Effects of consistent versus inconsistent retrieval demands. *Journal of Cognitive Neuroscience, 18,* 1531–1544.
Johnson, J. D., & Rugg, M. D. (2006b). Modulation of the electrophysiological correlates of retrieval cue processing by the specificity of task demands. *Brain Research, 1071,* 153–164.
Koutstaal, W. (2006). Flexible remembering. *Psychonomic Bulletin & Review, 13,* 84–91.
Meister, I., Buelte, D., Sparing, R., & Boroojerdi, B. (2007). A repetition suppression effect lasting several days within the

semantic network. *Experimental Brain Research, 183,* 371–376.
Morrell, H. E. R., Gaitan, S., & Wixted, J. T. (2002). On the nature of the decision axis in signal-detection-based models of recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28,* 1095–1110.
Öztekin, I., & McElree, B. (2007). Proactive interference slows recognition by eliminating fast assessments of familiarity. *Journal of Memory and Language, 57,* 126–149.
Paller, K. A., & Kutas, M. (1992). Brain potentials during memory retrieval provide neurophysiological support for the distinction between conscious recollection and priming. *Journal of Cognitive Neuroscience, 4,* 375–391.
Paller, K. A., Voss, J. L., & Boehm, S. G. (2007). Validating neural correlates of familiarity. *Trends in Cognitive Sciences, 11,* 243–250.
Ranganath, C., & Paller, K. A. (1999). Frontal brain potentials during recognition are modulated by requirements to retrieve perceptual details. *Neuron, 22,* 605–613.
Ranganath, C., & Paller, K. A. (2000). Neural correlates of memory retrieval and evaluation. *Cognitive Brain Research, 9,* 209–222.
Rhodes, M. G., & Jacoby, L. L. (2007). On the dynamic nature of response criterion in recognition memory: Effects of base rate, awareness, and feedback. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33,* 305–320.
Rotello, C. M., & Heit, E. (1999). Two-process models of recognition memory: Evidence for recall-to-reject? *Journal of Memory and Language, 40,* 432–453.
Rugg, M. D., & Curran, T. (2007). Event-related potentials and recognition memory. *Trends in Cognitive Sciences, 11,* 251–257.
Rugg, M. D., Walla, P., Schloerscheidt, A. M., Fletcher, P. C., Frith, C. D., & Dolan, R. J. (1998). Neural correlates of depth of processing effects on recollection: Evidence from brain potentials and positron emission tomography. *Experimental Brain Research, 123,* 18–23.
Rugg, M. D., & Wilding, E. L. (2000). Retrieval processing and episodic memory. *Trends in Cognitive Sciences, 4,* 108–115.
Schloerscheidt, A. M., & Rugg, M. D. (2004). The impact of change in stimulus format on the electrophysiological indices of recognition. *Neuropsychologia, 42,* 451–466.
Singer, M., & Wixted, J. T. (2006). Effect of delay on recognition decisions: Evidence for a criterion shift. *Memory & Cognition, 34,* 125–137.
Skinner, E. I., & Fernandes, M. A. (2008). Interfering with remembering and knowing: Effects of divided attention at retrieval. *Acta Psychologica, 127,* 211–221.
Smith, M. E. (1993). Neurophysiological manifestations of recollective experience during recognition memory judgments. *Journal of Cognitive Neuroscience, 5,* 1–13.
Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117,* 34–50.
Srinivas, K., & Verfaellie, M. (2000). Orientation effects in amnesics' recognition memory: Familiarity-based access to object attributes. *Journal of Memory and Language, 43,* 274–290.
Stenberg, G., Johansson, M., & Rosén, I. (2006). Conceptual and perceptual memory: Retrieval orientations reflected in event-related potentials. *Acta Psychologica, 122,* 174–205.
Strack, F., & Förster, J. (1995). Reporting recollective experiences: Direct access to the memory systems? *Psychological Science, 6,* 352–358.
Stretch, V., & Wixted, J. T. (1998). On the difference between strength-based and frequency-based mirror effects in recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24,* 1379–1396.
Trott, C. T., Friedman, D., Ritter, W., & Fabiani, M. (1997). Item and source memory: Differential age effects revealed by event-related potentials. *NeuroReport, 8,* 3373–3378.
Troyer, A. K., & Craik, F. I. M. (2000). The effect of divided attention on memory for items and their context. *Canadian Journal of Experimental Psychology, 54,* 161–170.
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.
Tulving, E. (1983). *Elements of episodic memory*. Oxford: Oxford University Press.
Tulving, E. (1985). Memory and consciousness. *Canadian Psychology, 26,* 1–12.
Verfaellie, M., Giovanello, K. S., & Keane, M. M. (2001). Recognition memory in amnesia: Effects of relaxing response criteria. *Cognitive, Affective & Behavioral Neuroscience, 1,* 3–9.
Vilberg, K. L., Moosavi, R. F., & Rugg, M. D. (2006). The relationship between electrophysiological correlates of recollection and amount of information retrieved. *Brain Research, 1122,* 161–170.
Vilberg, K. L., & Rugg, M. D. (2007). Dissociation of the neural correlates of recognition memory according to familiarity, recollection, and amount of recollected information. *Neuropsychologia, 45,* 2216–2225.
Voss, J. L., & Paller, K. A. (2007). Neural correlates of conceptual implicit memory and their contamination of putative neural correlates of explicit memory. *Learning and Memory, 14,* 259–267.
Werkle-Bergner, M., Mecklinger, A., Kray, J., Meyer, P., & Düzel, E. (2005). The control of memory retrieval: Insights from event-related potentials. *Cognitive Brain Research, 24,* 599–614.
Wheeler, M. A., & Stuss, D. T. (2003). Remembering and knowing in patients with frontal lobe injuries. *Cortex, 39,* 827–846.
Wilding, E. L. (2000). In what way does the parietal ERP old/new effect index recollection? *International Journal of Psychophysiology, 35,* 81–87.
Wolk, D. A., Schacter, D. L., Lygizos, M., Sen, N. M., Holcomb, P. J., Daffner, K. R., et al. (2006). ERP correlates of recognition memory: Effects of retention interval and false alarms. *Brain Research, 1096,* 148–162.
Xiang, J. Z., & Brown, M. W. (1998). Differential neuronal encoding of novelty, familiarity and recency in regions of the anterior temporal lobe. *Neuropharmacology, 37,* 657–676.
Yonelinas, A. P. (2001). Consciousness, control, and confidence: The 3 Cs of recognition memory. *Journal of Experimental Psychology: General, 130,* 361–379.
Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language, 46,* 441–517.
Yovel, G., & Paller, K. A. (2004). The neural basis of the butcher-on-the-bus phenomenon: When a face seems familiar but is not remembered. *Neuroimage, 21,* 789–800.
Zimmer, H. D. (1995). Size and orientation of objects in explicit and implicit memory: A reversal of the dissociation between perceptual similarity and type of test. *Psychological Research, 57,* 260–273.
Zimmer, H. D., & Steiner, A. (2003). Color specificity in episodic and in object recognition with enhanced color impact. *European Journal of Experimental Psychology, 15,* 349–370.