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Memory for perceived and imagined pictures—an event-related potential study

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Abstract

Event-related potentials (ERPs) and behavioural measures were used to investigate recognition memory and source-monitoring judgements about previously perceived and imagined pictures. At study, word labels of common objects were presented. Half of these were followed by a corresponding picture and the other half by an empty frame, signalling to the participants to mentally visualise an image. At test, participants in a source-monitoring task made a three-way discrimination between new words and words corresponding to previously perceived and imagined pictures. Participants in an old/new-recognition task indicated whether test words were previously presented or not. In both tasks, correctly identified old items elicited more positive-going ERPs than correctly judged new items. This widely distributed old/new effect was found to have an earlier onset and to be of a greater magnitude for imagined than for perceived items. Task (source versus item-memory) affected the old/new effects over prefrontal areas and the reaction times to remembered old items. The present findings are consistent with the view that a greater amount, or a different type, of information is necessary for accurate source-memory judgements than for correct recognition, and moreover, that different types of source-specifying information revive at different rates. In addition, the results add weight to the view that the late widespread ERP-old/new effect is sensitive to the quality or the amount of information retrieved from memory.

Keywords: Episodic memory; Recollection; Source-monitoring; Old/new effect

1. Introduction

Memory may fail us in several different ways. We may recognise a familiar face that occurs in a new context without being able to link that person to any particular earlier episode. We may remember a statement, yet be unable to specify who made it; and we may spuriously remember having done something that we merely planned to do. Failures to accurately retrieve information about the episode in which a memory was acquired have been suggested to be of vital importance in a wide range of areas, such as eyewitness suggestibility (e.g. [34]), cryptomnesia (e.g. [36]), and confabulation (e.g. [42]). A growing body of empirical results supports the notion that the ability to remember the source of information held in memory can be dissociated from the ability to accurately recognise previously encountered items. The suggested distinction between item and source-memory is the focus of the present study.

Support for the distinction comes from several studies that have reported dissociations between measures of item and source-memory performance. For example, compared with young adults, older adults generally display greater source than item-memory decrement (see [67] for a review). In parallel, brain damage may lead to an impaired source-memory performance while leaving item-memory intact [60,63]. Since source-memory performance is correlated with neuropsychological measures of frontal-lobe functioning [21] and selectively impaired following lesions in these regions [25,70], the prefrontal cortex has been suggested to be involved in processes related to remembering contextual information about the study episode. Recently, a number of electrophysiological and neuroimaging studies support this view (e.g. [29,53,62,69]), although prefrontal activation has been observed in item-recognition tasks as well (see [10] for a review).

An influential attempt to specify the processes involved in mnemonic behaviour has come from dual-process theories of recognition memory (e.g. [6,23,24,35]). In one such model, two independent processes are proposed to mediate recognition memory judgements, namely, familiarity and

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recollection [23]. The feeling of familiarity is held to be the result of an automatic attribution of the relative ease or fluency of processing (e.g. perceptual fluency). Compared with a new item in a recognition test, an old item is more readily processed, which makes it more likely to feel familiar and provides the basis for an "old" response [71]. Recollection, on the other hand, is described as a consciously controlled retrieval of source-specific information from episodic memory. Thus, the heuristic process of familiarity is sufficient for accurate item-recognition, whereas systematic memory retrieval is required for successful source-memory performance. A somewhat different account of the relation between item and source-memory is proposed by the source-monitoring framework (SMF).

The SMF has been developed to account for processes involved in making attributions about the source, or origin, of information held in memory ([27]; see [28] for a review). A central tenet of the framework is that source information is not automatically recovered when memory records are activated; instead, the source of a particular memory is inferred through decision processes during remembering. According to the SMF, source judgements are based on an assessment of the distribution of various qualitative characteristics of memories, most importantly records of perceptual information, contextual information, semantic detail, affective information, and cognitive operations (records of e.g. organising and elaborating during encoding). Memories acquired from different sources tend to be associated with differing relative amounts and types of such attributes, allowing source-monitoring processes to take advantage of these differences as cues for source decisions. As is explicit in the dual-process models, the SMF also posits heuristic and more systematic processes. While source decisions in general are made heuristically and rapidly, strategic retrieval of supporting memories and reasoning is sometimes needed. Although relatively more time-consuming, these systematic processes may provide an additional plausibility check of the outcome of the more heuristic source-attribution mechanism.

In the SMF, item-memory (i.e. recognition) and source-memory are not thought of as two fundamentally different processes. Instead, it is suggested that they can both be accounted for by referring to the heuristic and systematic processes outlined above [28]. Different memory tasks vary in what type of information they draw on, and in the specific decision criteria adopted. The SMF refers to two basic ideas to explain the relation between item and source-memory judgements. The first is that activation becomes increasingly differentiated as a function of continued stimulus processing, yielding more specific attributes in memory (i.e. memory characteristics such as perceptual, contextual, and semantic detail). These attributes are not simultaneously activated, and hence, revive and become available to the source-monitoring mechanism at different time-points. The second idea is that, although overlapping to a certain extent, different memory tasks require different levels of differentiation. For example, while relatively undifferentiated information such as fluctuating levels of perceptual fluency (or familiarity) would be sufficient to make an accurate old/new-discrimination, more differentiated information containing source-specific attributes (e.g. spatial position, encoding task requirements, etc.) is necessary for correct source-monitoring.

Behavioural results that support the basic claims of the SMF come from a study by Johnson et al. [30], in which the time-course of old/new-recognition and source-monitoring was examined by means of the response-signal speed-accuracy trade-off procedure [47]. Participants were instructed to make a three-way discrimination between new words and words corresponding to previously perceived and imagined pictures (i.e. reality-monitoring [31]) at varying intervals after the onset of the test word (time lags were 300, 400, 500, 900, and 1500 ms and an unconstrained response time condition). Multinomial-processing models [7] were applied to the data, yielding estimates that allowed examination of memory performance as a function of processing time. Given that one accepts the model proposed by the authors as veridical (see [38] for remarks concerning this, as well as some methodological issues), two results are of primary importance. First, old/new-recognition accuracy was above chance at an earlier time-point than reality-monitoring accuracy. Although both improved as more processing time was allowed, participants were able to discriminate between old/new items at the shortest lag (300 ms), whereas more time was needed for correct source identification. Second, the results revealed time-course differences between the two types of source-attributions. The participants were able to identify the origin of imagined items well before correct source judgements were made for perceived items: 400 ms versus 1500 ms in Experiment 1; and 300 ms versus 500 ms in Experiment 2 (note that source accuracy for imagined items was above chance at the same lag as old/new-discrimination in Experiment 2). Although there was a disparity in the absolute values across experiments (which the authors attributed to procedural differences), the same pattern emerged: correct source identification required shorter processing time for imagined than for perceived items. The authors argued that, since memory for imagined items should contain more information about cognitive operations performed during imagery, the results indicate that records of this type of memory characteristic revive earlier than records of perceptual detail (which, in turn, should be more prominent for perceived items). Altogether, the results were held to be consistent with the predictions derived from the SMF. First, source-monitoring requires a greater amount, or a different type, of information than old/new-recognition. Second, memories from different sources differ in the amount and/or types of information. Third, different types of memory characteristics become available at different time-points to source-attribution processes, or differ in relative salience during reality-monitoring.

The purpose of the present study was to further examine these issues by using event-related potentials (ERPs) in addition to behavioural measures. Since ERPs have a very high temporal resolution, they provide important measures when the time-course of cognitive processes is being considered. Furthermore, in the present context, the technique has the advantage that it minimises demands on the participants. In contrast to the response-signal procedure, electrophysiological time-course data can be recorded in a test situation, where the participants are allowed to process the probe word until a confident judgement can be made. For example, it seems plausible that participants may adopt quite different strategies when asked to respond after 300 ms compared to making the same judgement when 1500 ms of processing time is given. It is, thus, hard to disentangle whether an observed pattern of results is due to different decision processes, different criteria adopted, or the different rates at which various types of information differentiate. Hence, the use of ERPs has the potential to provide complementary time-course data of reality-monitoring processes without necessitating a comparison of performance across different conditions that may not be equivalent with respect to the processes they tap. We now turn to some relevant results stemming from memory studies using electrophysiological measures.

A number of studies have shown that ERPs are sensitive to mnemonic processes during remembering (see [32,48] for reviews). Remembered old items generally elicit more positive-going ERPs than those elicited by correctly judged new items. Importantly, this so called "old/new effect" effect is absent for undetected old words and new words falsely endorsed as old (e.g. [44,52,74]), which suggests that it indexes neural activity associated with retrieval of information about a prior event rather than with stimulus repetition alone or merely responding "old". It has been suggested that the old/new effect observed during episodic memory may comprise a number of spatio-temporally specific sub-components that reflect different aspects of retrieval [20,40]. Interpreted within the context of dual-process models, an early (300–500 ms post-stimulus) old/new effect has been linked to familiarity and is assumed to evolve from an attenuation of a frontal N400-like component for old items [14,15,39,41,56], whereas the enhancement of a late positive component (400–800 ms), typically, maximal at left parietal regions (but see, e.g. [69] for a spatially widespread effect) is held to index recollection [3,46,51,65,72–74,76]. For example, Curran [15] reported that while both studied words and similar words (switched plurality between study and test) showed the frontal effect, only studied words were associated with the parietal effect. Furthermore, the parietal effect is of greater magnitude for items that participants "remember" (item + context retrieval) relative to those that participants merely "know" (item retrieval only) as previously studied [17,65] and for items correctly assigned to their study context [72–74,76], thereby strengthening the link to recollection.

In a number of studies with tasks that include an explicit requirement to retrieve information about the study context of each recognised item, a frontally distributed old/new effect has been described that is more sustained over time and tends to be lateralised to the right hemisphere ([49,58,62,68,69,74–76], but see, e.g. [2,61] for the effect in mere item-recognition tasks). Different proposals have been put forward to account for this effect: post-retrieval processes operating on the products of retrieval [74]; monitoring and verification processes [49]; and strategic search for source information [62,68,69].

A few recent studies have directly compared ERPs elicited in item and source-memory tasks [29,62,69]. Senkfor and Van Petten ([62]; see also [69]) observed a late bilateral prefrontal old/new effect when participants were required to make source-memory judgements (speaker's voice) that was absent when a mere item-recognition task was employed. As the effect was equivalent for correct and incorrect source judgements, the authors proposed that prefrontal regions are involved in attempting to retrieve information about the study context, rather than acting on the products of retrieval. Likewise, neural activity recorded at prefrontal sites evoked by items attracting correct responses (both studied and unstudied) have been observed to differ as a function of memory task [29].

Capitalising on the ERP memory effects, the present study examined item- and source-memory judgements to words corresponding to previously perceived and imagined pictures. The primary aim was to explore whether any electrophysiological support for the interpretations of Johnson et al. [30] could be found. More precisely, will the old/new effects for perceived and imagined pictures differ with regard to onset-latency, amplitude and/or scalp-distribution? In order to minimise the complexity of interpreting any differences, the ERPs were recorded in a task that allowed very high item- and source-memory performance, equal for both types of old items. The reason for this was twofold: first, it allowed stable ERPs to be formed with as low susceptibility to noise as possible, and second, it permitted averaging to be done across trials with a maximal probability of recollection as the basis for correct responses to both perceived and imagined pictures (i.e. including source-specifying information). The notion that records of cognitive operations revive earlier than perceptual detail would predict an earlier time-course for imagined items compared with perceived. Furthermore, the SMF posits that source-monitoring judgements can be based on, not only different amounts, but also different types of information (e.g. perceptual detail versus records of cognitive operations). Johnson et al. [29] observed negative deflections in the waveform for correct responses that differed in scalp-distribution according to encoding task. Since these differences were found for both correctly judged old/new items, the authors hypothesised that they reflected what type of memorial information participants were consulting or trying to recover during remembering. In the present study, we investigated whether the ERP-old/new effects associated with successfully retrieved perceived and imagined items differed in their scalp topographies (see [1], for a similar examination of ERP cued recall effects). Following the logic of Rugg and Coles [50], such a result would provide evidence in favour of the view that memory for perceived and imagined items involve neurologically/functionally non-equivalent processes and, thus, support the notion that memory judgements to perceived and imagined items are based on different types of information. Finally, the present study employed both an old/new-recognition task and a reality-monitoring task to provide additional results regarding the association between prefrontal regions and the explicit requirement to retrieve source-specific information.

2. Method

2.1. Participants

Thirty-three participants, all students at Lund University, were paid to take part in the experiment. The data from one participant were excluded due to equipment malfunction. Of the remaining 32 participants, 13 were female. The mean age of the participants was 25 years (range = 20–35) and all were right-handed, as defined by preferred writing hand. Half of the participants were assigned to the reality-monitoring task, and half to the old/new-recognition task.

2.2. Experimental material

A total of 304 black-and-white line drawings of common objects (e.g. bike, chair, and toast) were collected from the following picture sets: Snodgrass and Vanderwart [66], the Boston Naming Test [33], Ordracet [18], Skånes benämningsprövning [5], and Fonemtest [22]. As in the Johnson et al. [30] study, a picture was selected if it could be described by a one-word label, and moreover, if this one-word label was specific and concrete enough to evoke a corresponding mental image. The resulting stimuli were used to form four sets, each containing 76 pictures with corresponding word labels. The sets were matched for word length (range = 3–10 letters), and word frequency (range =< 1–482 per million [4]). Average length in the four sets was 5.8 (S.D. = 1.8), 5.9 (S.D. = 2.0), 5.7 (S.D. = 1.9), and 5.8 (S.D. = 1.9), [$F(3, 300) = 0.106$, NS]. Mean word frequency was 19.3 (S.D. = 58.7), 19.2 (S.D. = 41.6), 19.3 (S.D. = 52.5), and 19.2 (S.D. = 46.3), [$F(3, 300) < 0.001$, NS].

Items used in the study phase were collected by combining two of the sets, one in which items were assigned to the perceived condition, and one containing items to be imagined. Presentation order of study items was randomly determined. The four sets appeared, across participants in each group, equally often in the perceived as in the imagined condition.

Test lists were then created by combining all four stimulus sets, resulting in a total of 152 old items (76 perceived and 76 imagined) and 152 new items. As in the study phase, presentation order was randomly determined. Across participants in each group, the four sets appeared the same number of times as old/new items.

2.3. Procedure

The experiment was run using PsyScope [11] on a Macintosh IIfx computer connected to a 13-in. Apple monitor. The screen background colour was set to white, and all stimuli were displayed at the centre of the screen, with word stimuli presented in black 24-point Chicago typeface.

The study phase was closely modelled after that used in the Johnson et al. ([30], Experiment 2) study. Participants were told that this part of the experiment was a test of aesthetic perception and visual imagination. Each trial began with a fixation cross (500 ms) preceding the presentation of a word label (1500 ms). On half of the trials, word labels were followed by a rectangular 460 × 400-point frame, enclosing a picture corresponding to the word label. On the other half of the trials, word labels were followed by an empty frame. Participants were instructed to look at the displayed picture in the first case and imagine a picture of the named object in the second case. On the imagined item trials, participants were encouraged to visualise line drawings like the ones displayed on perceived item trials, and to mentally project these images inside the frame on the screen. Both empty frames and frames that enclosed pictures were displayed for 6000 ms. During this time, participants were asked to consider how well the picture (or image) illustrated the object in question. Participants were told to use artistic merit and clarity of representation as relevant criteria for the judgement. In addition, participants were asked to attempt to apply these criteria equivalently to the perceived and the imagined pictures. Each trial then ended with the instruction to rate each picture (or image) on a three-alternative scale: "Good", "Adequate", or "Poor". Participants pressed a key corresponding to their decision and the next trial began. Before the study phase began, participants received four practice trials to ensure that task instruction was fully comprehended. The study phase was divided into four blocks by short subject-terminated breaks. In total, the study phase comprised 152 single-word object labels, whereof corresponding pictures of 76 objects were perceived and 76 imagined.

After a short rest, participants were given instructions for the test phase. Each trial consisted of a fixation cross (1500 ms), which disappeared 500 ms before the onset of the test word. Test words were presented for 200 ms and were then followed by a 3800 ms response interval. The only difference between the groups was in the task instructions. Participants in the old/new-recognition task were told to use their left and right index fingers to indicate whether a test item was presented in the study phase ("old"), or not ("new"). In the reality-monitoring task, participants were instructed to use the index and second fingers of one hand to press separate keys if a test item corresponded to a previously perceived picture ("perceived"), or imagined picture ("imagined"). Key presses with the other hand were used to reject test items that were new to the experiment ("new"). The mapping between hand and response was counterbalanced across participants in both groups, as was the mapping between finger and source judgement in the reality-monitoring task. Participants in both groups were instructed to make their memory judgements as accurately and quickly as they could. The test phase was divided into four blocks by short subject-terminated breaks.

As both perceived and imagined pictures were preceded by a word label in the study phase, any observed differences in the old/new effect for perceived and imagined items should reflect a sensitivity to whether the subsequent picture was seen or mentally visualised, and not be affected by, for example, varying levels of perceptual fluency.

To reduce EEG artefacts, participants were told to remain relaxed throughout the test phase and to avoid eye blinking during presentations of test words. Following the test phase, the experiment was completed with a debriefing, which included a short interview to reveal phenomenological aspects of the memory test.

2.4. ERP recording

Continuous EEG was recorded from 17 Ag-electrodes. The montage included five mid-line sites (Fpz, Fz, Cz, Pz, and Oz), and six pairs of lateral sites (Fp1/Fp2, F3/F4, C3/C4, P3/P4, T5/T6, and O1/O2), based on the International 10-20 system [26]. The EEG from all sites was recorded with reference to linked earlobe electrodes. Additional electrodes located below the right eye, and outside the outer canthi of both eyes, were used to monitor eye movements and blinks. All channels were amplified with a band-pass from 0.1 to 50 Hz with a 6 dB per octave roll-off, and digitised with 4 ms resolution, using a NeuroScan system. Further off-line data processing included a digital low-pass filter set to 35 Hz. The EEG epochs used for analyses had a duration of 2200 ms, starting 200 ms prior to stimulus onset. The pre-stimulus sampling period was used for base-line correction of each recording epoch. Trials on which EEG activity exceeded $\pm 100\,\mu V$ after correction for oculomotor artefacts, or with artefacts due to amplifier saturation, were rejected prior to averaging.

Average ERPs were calculated for three conditions: hits to words corresponding to perceived pictures, hits to words corresponding to imagined pictures, and correct rejections of new words. Averaging was done separately for the two memory tasks: reality-monitoring and old/new-recognition. This procedure allowed analyses of old/new effects separately for perceived and imagined items in addition to comparisons across memory task.

3. Results

For all conducted analyses of variance (ANOVAs), the Greenhouse–Geisser adjustments for non-sphericity [77] were used when appropriate, and the corrected degrees of freedom are reported in Section 3.1.

3.1. Behavioural data

Memory performance and reaction time measures are shown for each task and item type in Table 1. To examine participants' ability to discriminate between old/new items, a recognition index was calculated separately for perceived and imagined items in both tasks [$P(\text{old response}) - P(\text{false alarm})$]. To facilitate across-task comparisons, these measures were based on all correct "old" judgements in the reality-monitoring task, irrespective of whether these were associated with accurate source-attributions or not. As can be seen in Table 1, while performance appears equally high for perceived and imagined items, discrimination accuracy appears to be higher in the reality-monitoring task. A two-way ANOVA was conducted on the recognition index, employing the factors of task (reality-monitoring versus old/new-recognition) and item type (perceived versus imagined). This analysis revealed the single significant main effect of task [$F(1, 30) = 11.08$, $P < 0.01$]. Thus, regardless of item study status,

Table 1
Memory performance and reaction time measures displayed separately for each item type and memory task[a]

Task and item type	"Old" response (*P*)	Recognition index (*P*)	Correct source (*P*)	Reaction time (ms)
Reality-monitoring				
Perceived	0.95 (0.04)	0.93 (0.05)	0.90 (0.06)	1458 (240)
Imagined	0.95 (0.04)	0.92 (0.04)	0.91 (0.05)	1500 (308)
New	0.02 (0.01)			1221 (263)
Old/new-recognition				
Perceived	0.92 (0.05)	0.87 (0.07)		1002 (158)
Imagined	0.93 (0.04)	0.88 (0.07)		1025 (186)
New	0.04 (0.04)			1140 (248)

[a] Standard deviations are given in parentheses.

participants in the reality-monitoring task were able to discriminate between old/new items to a higher degree than participants in the old/new-recognition task.

Data from the reality-monitoring task allowed analysis of participants' ability to identify the correct source of recognised items. As can be seen in Table 1, perceived and imagined items were attributed to their correct source at similar rates. An index of source-monitoring was calculated and indicated high accuracy: 0.90 (S.D. $= 0.09$), [P(correct source-attribution) $-$ P(wrong source-attribution)]/[P(correct source-attribution) $+$ P(wrong source-attribution)]. In summary, memory performance was equivalent for perceived and imagined items in old/new-discrimination accuracy and near error-free in source-attribution accuracy.

Reaction times for correct responses were analysed by a two-way ANOVA using task (reality-monitoring versus old/new-recognition) and item type (perceived versus imagined versus new) as factors. It revealed a significant main effect of task [$F(1,30) = 17.57$, $P < 0.001$], type [$F(1.7, 50.8) = 6.79$, $P < 0.01$], and a significant interaction involving the two factors [$F(1.7, 50.8) = 49.48$, $P < 0.001$]. Follow up analyses using Bonferroni adjustments for multiple comparisons showed that: reaction times for hits to perceived and imagined items did not differ in the reality-monitoring task, nor in the old/new-recognition task; and further, that both types of hits were significantly different from correct rejections in both memory tasks. As can be seen in Table 1, reaction times for hits were faster than correct rejections in the old/new-recognition task, while the opposite pattern was found in the reality-monitoring task. No task-related difference was found when the reaction times to correctly rejected new items were contrasted [$t(30) < 1$, NS].

3.2. ERP data

Grand averages for hits to perceived and imagined items, and correct rejections are shown separately for the reality-monitoring task and the old/new-recognition task in Figs. 1 and 2, respectively. The mean number of trials included in each grand average was 57, 59, and 121 in the reality-monitoring task, and 59, 60, and 123 in the old/new-recognition task. As can be seen in Fig. 1, ERP waveforms in the reality-monitoring task began to deviate from one another approximately 400 ms post-stimulus-onset. This difference consisted of more positive-going ERPs being evoked by old items compared to new. The positive shift was evident over all recording sites and lasted

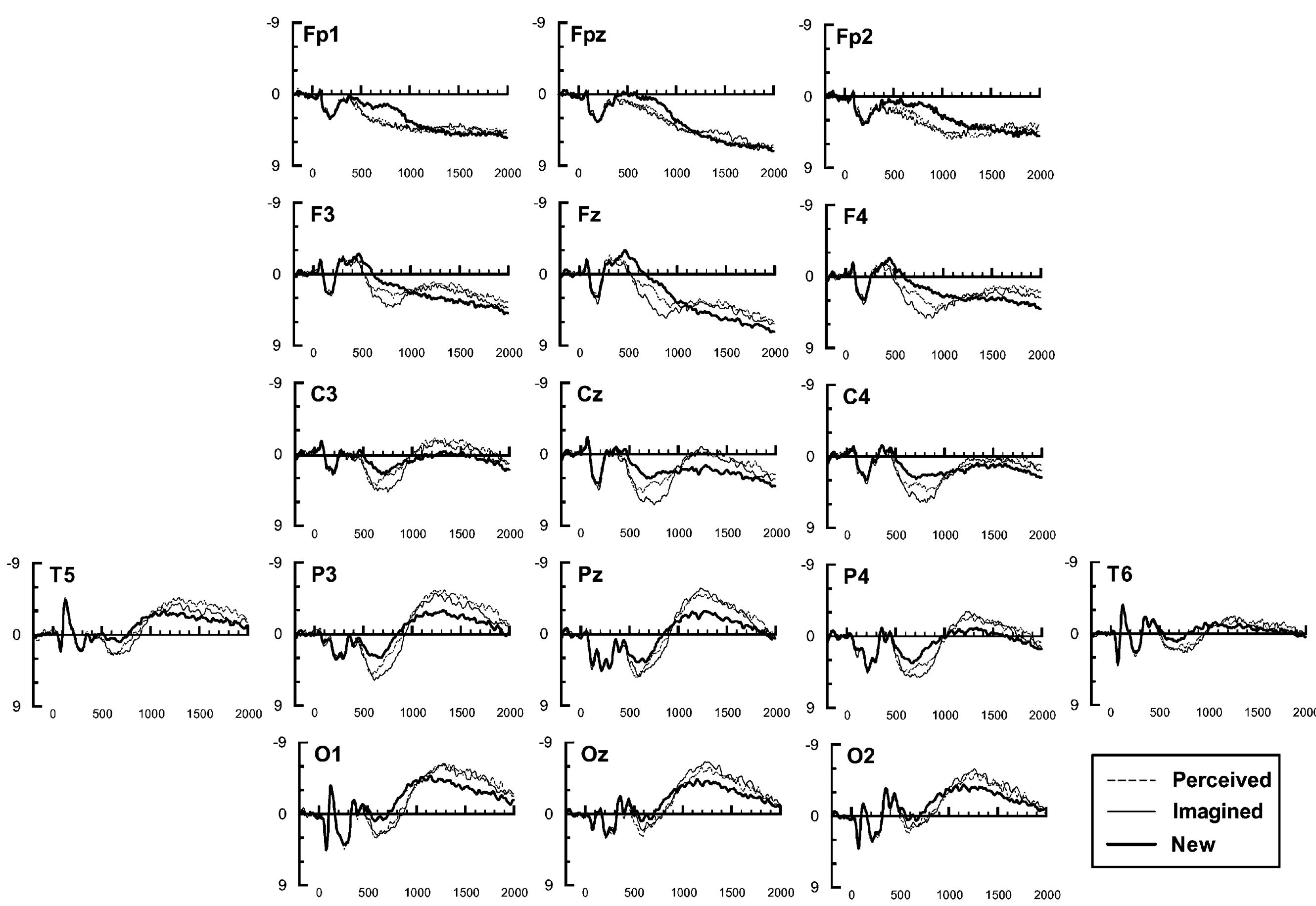

Fig. 1. Grand average ERPs to correct responses to perceived, imagined, and new items in the reality-monitoring task. Amplitudes are displayed in μV.

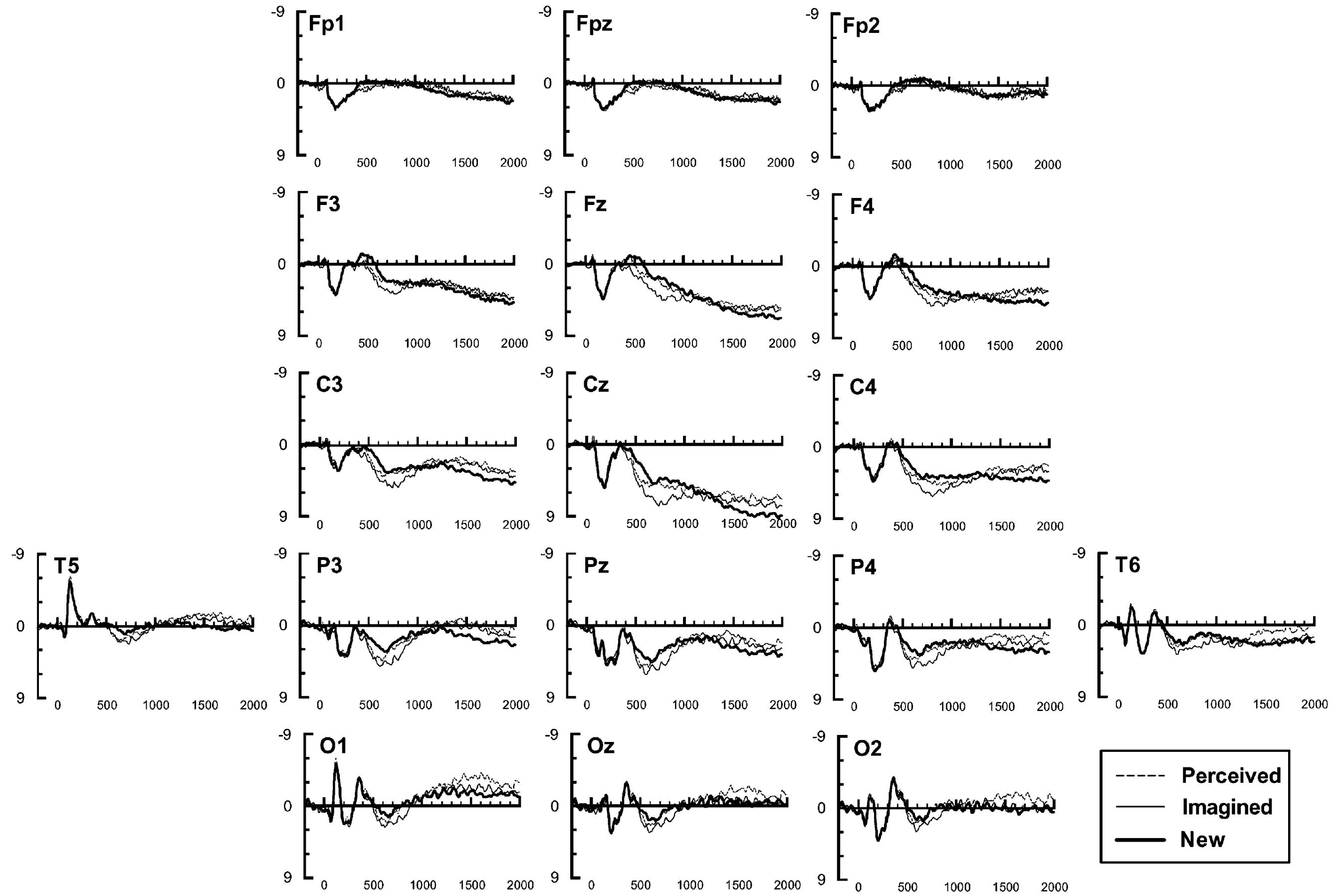

Fig. 2. Grand average ERPs to correct responses to perceived, imagined, and new items in the old/new-recognition task. Amplitudes are displayed in μV.

approximately 600 ms and somewhat longer over frontally located regions. Visual inspection of the waveforms further suggests that this widespread old/new effect was greater in magnitude for ERPs elicited by imagined items than for perceived. At a majority of electrodes, this positivity was replaced by a late negative-going deflection in the waveforms that again differentiated old/new items. In addition, this negative-going old/new effect appeared to be greater for perceived items compared with imagined items over the left tempero-parietal regions.

Turning to the old/new-recognition task displayed in Fig. 2, the ERPs show a similar pattern of effects. The most prominent exceptions to this are: first, that the widespread old/new effects associated with both perceived and imagined items appears to be slightly smaller than in the reality-monitoring task, and second, that this effect is almost absent over prefrontal recording sites. The late negative old/new effect observed in the reality-monitoring task is evident in the old/new-recognition task as well, however, to a somewhat lesser degree and with a less apparent asymmetry in favour of the left hemisphere. Furthermore, the negative shift appears to be larger for perceived items, especially, at occipital recording sites.

The participants' ERP data underwent a set of analyses described in two main sections below. First, we report outcomes from within-task analyses that aimed at revealing whether reliable old/new effects existed in the data, and further, to establish whether the old/new effects differed in magnitude or topography according to an item's study status. Included in the within-task analyses, we report estimates of the onset-latencies of the old/new effects for perceived and imagined items. Second, we report results from across-task analyses in which examination of the data recorded at prefrontal electrodes was of particular interest, based on previous findings [29,62,69].

3.2.1. *Within-task analyses*

ERPs were quantified by measuring the mean amplitude (relative to the 200 ms pre-stimulus baseline) in four consecutive time windows: 400–600, 600–900, 900–1200, and 1200–1800 ms. These time windows were selected based on previous research and inspection of the waveforms.

Separate analyses were performed on data from the reality-monitoring task and the old/new-recognition task over mid-line and lateral recording sites. However, results from analyses using data from the mid-line electrodes are not reported unless they add to the results obtained from the lateral recording sites. For each time window, an initial ANOVA using the factors of type (hits to perceived items versus hits to imagined items versus correct rejections), hemisphere (left versus right), and electrode position (Fp1/Fp2 versus F3/F4 versus C3/C4 versus P3/P4 versus T5/T6 versus O1/O2) was performed to demonstrate a reliable difference among response categories. In case of a significant effect involving the factor of type, three planned subsidiary analyses were conducted to contrast the three response categories in a pairwise fashion. This procedure permitted: first, a test of the reliability of the old/new effect separately for perceived and imagined items, and second, a test of whether the effects associated with the two types of old stimuli differed with respect to magnitude. For all conducted analyses, significant effects are reported only when there was a main effect of type, or an interaction involving this factor.

To examine the scalp-distributions for perceived and imagined items, difference measures (i.e. perceived minus new and imagined minus new) were calculated and re-scaled by the vector length method [37] to eliminate confounding effects of differences in magnitude. A single ANOVA using the factors of type and site (all 17 electrodes) was conducted on the re-scaled mean amplitudes in each time window that demonstrated reliable effects.

A final within-task analysis was performed, addressing the question of whether the old/new effects for perceived and imagined items were associated with different onset-latencies. Estimates were derived from point-by-point *t*-test comparisons between ERPs elicited by old/new items. Onset-latency was defined as the time-point that was followed by 24 (100 ms) consecutive significant *t*-values for the compared conditions (i.e. perceived-new and imagined-new) (e.g. [55]).

3.2.1.1. Reality-monitoring task. The initial ANOVAs in each time window revealed significant differences between response categories [400–600 ms: main effect of type $F(2, 30) = 11.12$, $P < 0.001$; 600–900 ms: main effect of type $F(2, 30) = 13.48$, $P < 0.001$; 900–1200 ms: type × hemisphere interaction $F(2, 30) = 5.53$, $P < 0.01$ and a three-way interaction between type, electrode position, and hemisphere $F(4.0, 59.8) = 2.66$, $P < 0.05$; 1200–1800 ms: main effect of type $F(2, 30) = 6.30$, $P < 0.01$]. Thus, subsidiary analyses were conducted and the significant results of these can be seen in Table 2.

Reliable old/new effects were observed in the 400–600 ms time window for both perceived and imagined items. No significant differences were revealed when contrasting the two types of hits, indicating that perceived and imagined stimuli evoked a widespread memory effect of equal magnitude (see Fig. 3).

The old/new effects remained highly reliable in the 600–900 ms time window as well, but the effect was

Table 2
Results of the analyses of the mean amplitudes at lateral electrodes in the four time windows[a]

Task and time window	Pairwise comparison		
	Perceived vs. new	Imagined vs. new	Perceived vs. imagined
Reality-monitoring			
400–600 ms			
Type	$F(1, 15) = 13.87^{**}$	$F(1, 15) = 25.06^{***}$	–
600–900 ms			
Type	$F(1, 15) = 10.13^{**}$	$F(1, 15) = 20.52^{***}$	$F(1, 15) = 5.52^{*}$
Type × POS × HEM	–	–	$F(5, 75) = 2.52^{*}$
900–1200 ms			
Type × HEM	$F(1, 15) = 7.02^{*}$	$F(1, 15) = 5.11^{*}$	–
Type × POS × HEM	–	$F(2.5, 37.5) = 4.12^{*}$	–
1200–1800 ms			
Type	$F(1, 15) = 9.32^{**}$	$F(1, 15) = 11.30^{**}$	–
Type × HEM	$F(1, 15) = 4.76^{*}$	–	$F(1, 15) = 6.41^{*}$
Old/new-recognition			
400–600 ms			
Type	–	$F(1, 15) = 12.78^{**}$	–
600–900 ms			
Type	–	$F(1, 15) = 10.54^{**}$	$F(1, 15) = 6.23^{*}$
900–1200 ms			
Type × HEM	–	$F(1, 15) = 5.73^{*}$	–
1200–1800 ms			
Type	$F(1, 15) = 4.73^{*}$	–	–
Type × POS	$F(2.2, 33.0) = 5.54^{**}$	–	$F(2.1, 31.4) = 4.10^{*}$

[a] Significant effects involving the factor of type are reported separately for the two memory tasks. HEM = hemisphere (left vs. right), POS = electrode position (Fp1/Fp2 vs. F3/F4 vs. C3/C4 vs. P3/P4 vs. T5/T6 vs. O1/O2).

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

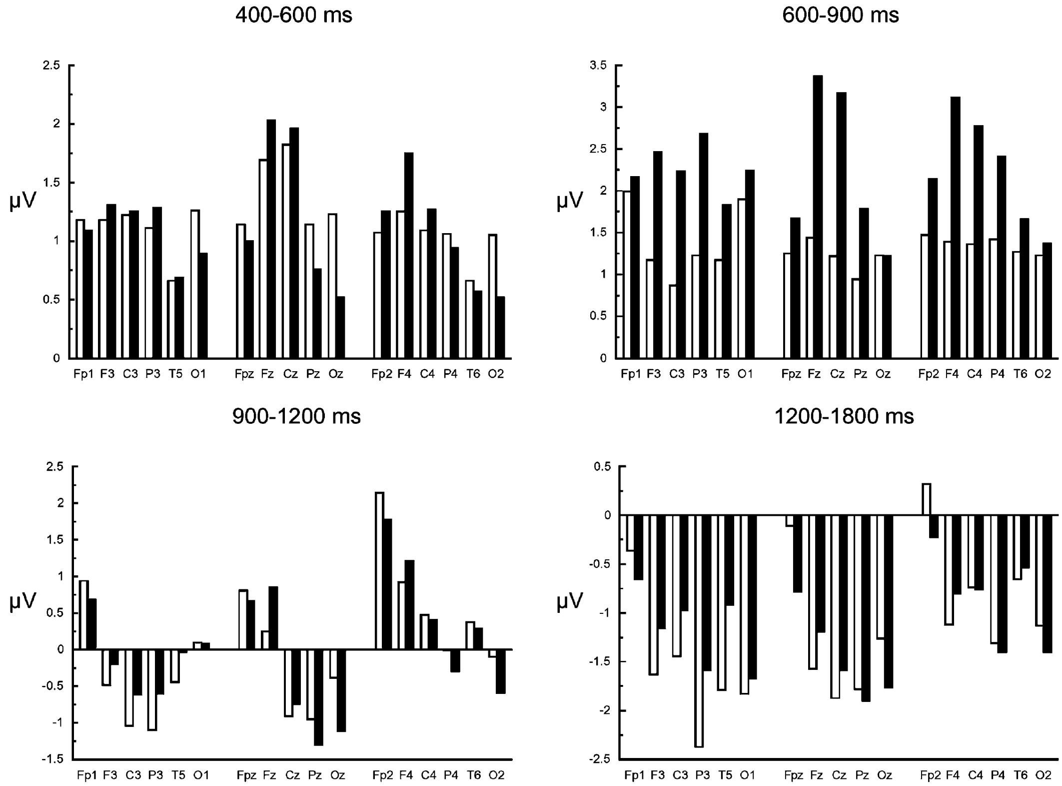

Fig. 3. Difference measures in the reality-monitoring task displayed separately for each time window. Amplitudes are represented by the white and black bars, which represent the old/new effect for perceived and imagined items, respectively.

significantly greater in magnitude for imagined items compared with perceived (2.25 µV versus 1.37 µV, averaged over all lateral sites). As can be seen in Table 2, the comparison between perceived and imagined stimuli gave rise to a type × electrode position × hemisphere interaction, reflecting the fact that the difference between perceived and imagined tended to show a right > left pattern at anterior electrode pairs, but a left > right pattern at posterior electrode pairs (see Fig. 3).

The ANOVAs for the 900–1200 ms interval showed that while the difference between perceived and new items remained positive over the right hemisphere, it tended to change into the opposite direction over the left hemisphere. This pattern was observed for imagined items as well, in addition to a significant interaction between type, electrode position, and hemisphere. As suggested in Fig. 3, this latter effect reflected the fact that the positive difference between imagined items and new items was restricted to frontally located electrodes, and furthermore, that the effect was greatest in magnitude over the right hemisphere. These findings are in accord with previous studies reporting a sustained effect over the right frontal regions [58,74–76].

Turning to the 1200–1800 ms time window, the difference between old/new items was characterised by a widespread negative-going effect that was reliable for both perceived and imagined items. As suggested by Figs. 1 and 3, while this late old/new effect was observed bilaterally for imagined items, it exhibited an asymmetry in favour of the left hemisphere for perceived items (maximal at P3). Thus, a difference in magnitude between the effects for perceived and imagined items was restricted to the left hemisphere.

Since significant effects involving the factor of type were observed in each time window, comparisons of the scalp topographies associated with the old/new effects for perceived and imagined items were conducted as described above. However, the outcomes of these ANOVAs failed to reveal any interactions between type and recording site (maximum $F = 1.28$, NS), indicating that the old/new effects for perceived and imagined items exhibited statistically similar topographies.

The electrode that first complied with the criterion used to derive estimates of onset-latencies was for both types of old items Fz. The results of the analysis suggest a slight difference in onset-latency: 432 and 388 ms for perceived and imagined items, respectively (see Fig. 4). To reduce the risk of unstable data using only one electrode, mean onset-latency values were computed for the five earliest electrodes that met the criterion (perceived: Fz, F4, Cz, O1/Oz, O2; imagined: F3, Fz, F4, Cz, C4). The difference in onset-latency between old items still remained, with 460 ms for perceived items and 420 ms for imagined. Fig. 5 depicts the mean onset-latencies at frontal, central, and parietal sites for which estimates could be derived and compared for both types of old items. As suggested by the figure, the

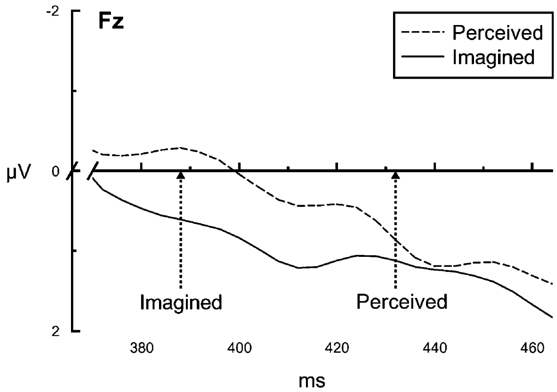

Fig. 4. Difference waveforms (i.e. old − new) shown for perceived and imagined items at Fz in the reality-monitoring task. The vertical arrows depict the estimated onset-latencies for perceived (432 ms) and imagined items (388 ms).

old/new effect began at frontal sites showing an imagined < perceived pattern, whereas there was a tendency for the opposite pattern across posterior sites later on in the epoch. This exploratory analysis, thus, suggests that the old/new effect appeared somewhat earlier for imagined stimuli compared with perceived at frontal sites.

In addition, we set out to examine whether the observed difference in onset-latencies would prove statistically significant. In order to do this, separate onset estimates for perceived and imagined old/new effects were derived for each participant and recording site. Onset-latency estimates were defined as the time-point that was followed by 24 (100 ms) consecutive difference measures (i.e. perceived minus new and imagined minus new) >1 μV. Due to a considerable number of missing values and as the old/new effects did not show any hemispheric asymmetry, onset estimates were collapsed across the left–medial–right dimension. As implied by the across-subjects analysis, onset-latency estimates were found to be reliably shorter for imagined items than for perceived, $t(15) = 2.41$, $P < 0.05$, at frontal sites. No other comparisons proved reliable.

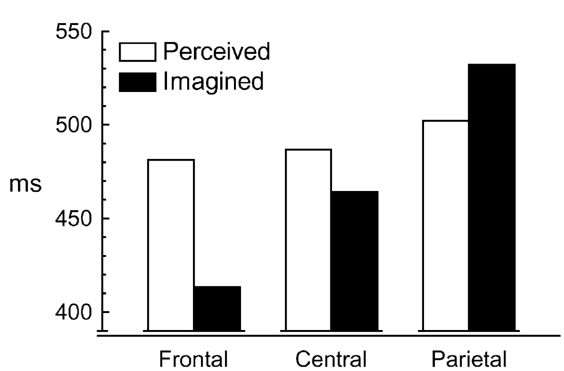

Fig. 5. Mean onset-latency estimates for the frontal, central, and parietal sites at which estimates for both old item types were derived. White bars represent perceived items and black bars imagined items.

Before turning to the old/new-recognition task we report an exploratory analysis of the old/new effect at prefrontal and frontal sites in the reality-monitoring task. Looking at Fig. 1, it appears as if the old/new effect at prefrontal sites might be functionally distinct from the effect observed at frontal sites. Specifically, while there is a clear magnitude difference in the old/new effect for perceived and imagined items at frontal sites, no such difference is evident at the prefrontal sites. An ANOVA was conducted on the difference measures with the factors of time window (400–600 ms versus 600–900 ms versus 900–1200 ms), item type (perceived versus imagined), electrode position (prefrontal versus frontal), and hemisphere (left versus right). The results revealed a significant interaction between time window, type, and electrode position [$F(1.8, 27.0) = 4.77$, $P < 0.05$] that reflected the fact that the magnitude difference between item types was evident at frontal, but not at prefrontal sites in the 600–900 ms time interval. However, no significant effects involving type and electrode position was found reliable when re-scaled data were used, and we are therefore, reluctant to interpret the pattern of results as a functional differentiation between prefrontal and frontal regions.

3.2.1.2. Old/new-recognition task. As in the reality-monitoring task, the initial ANOVAs in each time window revealed significant differences between response categories [400–600 ms: main effect of type $F(2, 30) = 6.20$, $P < 0.01$; 600–900 ms: main effect of type $F(2, 30) = 6.82$, $P < 0.01$; 900–1200 ms: type × hemisphere interaction $F(2, 30) = 3.47$, $P < 0.05$; 1200–1800 ms: type × electrode position interaction $F(3.6, 54.6) = 3.69$, $P < 0.05$]. Thus, subsidiary analyses were conducted and the significant results of these can be seen in Table 2.

ANOVAs conducted on data from the 400–600 time window revealed a reliable old/new effect for imagined items. Although the difference between perceived and new items showed a similar effect (see Fig. 6), it did not reach the level of significance at lateral recording sites. Data from mid-line electrodes, however, gave rise to a marginally significant main effect of type [$F(1, 15) = 4.21$, $P < 0.06$], reflecting more positive ERPs to perceived items than to new. The ANOVA contrasting perceived and imagined items directly revealed a main effect of type when mid-line electrodes were used [$F(1, 15) = 5.65$, $P < 0.05$], indicating a greater old/new effect for imagined items. No significant difference between conditions was found when lateral electrodes were used.

While a reliable old/new effect remained for imagined items in the 600–900 ms interval, no such effect was found reliable for perceived items. For imagined items, data from mid-line electrodes revealed a significant interaction between type and electrode position [$F(1.9, 29.1) = 5.10$, $P < 0.05$], which reflected the fact that the old/new effect was maximal over central electrodes and attenuated in the anterior as well as in the posterior direction. Furthermore, a reliable difference was observed between the two types

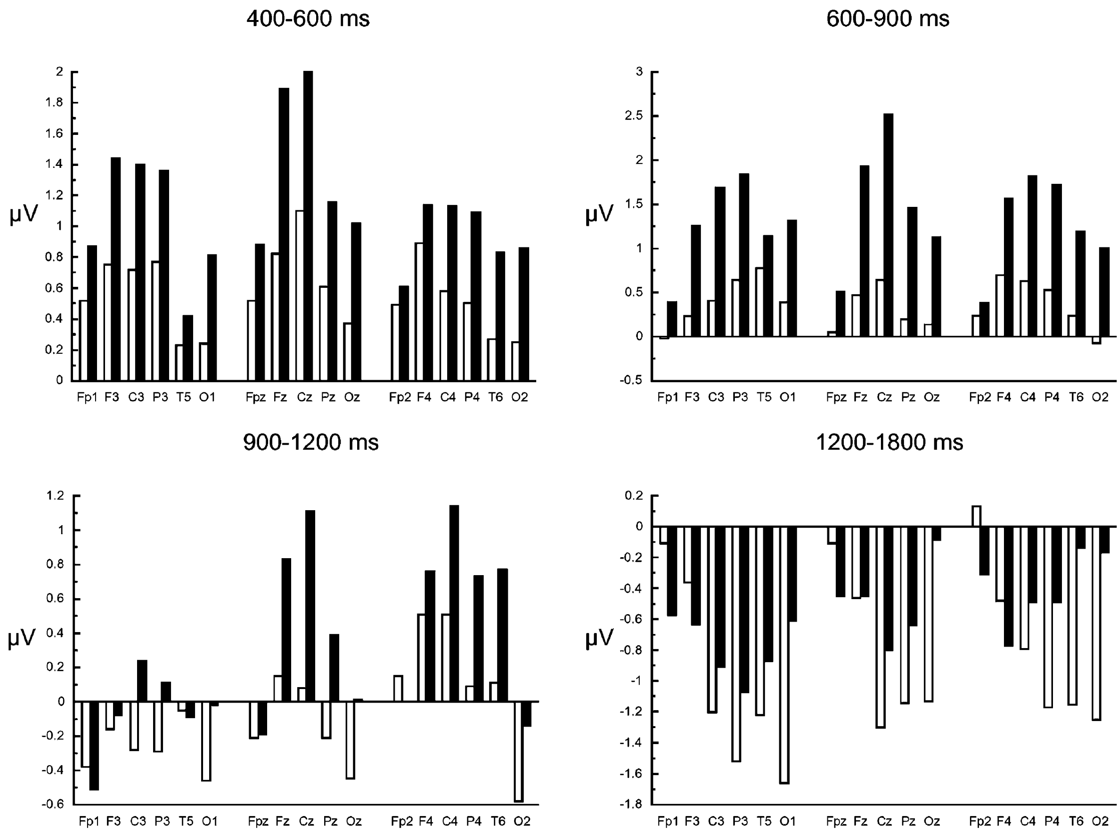

Fig. 6. Difference measures in the old/new-recognition task displayed separately for each time window. Amplitudes are represented by the white and black bars, which represent the old/new effect for perceived and imagined items, respectively.

of old items at lateral recording sites, demonstrating more positive ERPs elicited by imagined items than by perceived.

As observed in the reality-monitoring task, the outcomes of the analyses in the 900–1200 ms time window showed that the positive difference between imagined and new items was more prominent over the right hemisphere. However, in the old/new-recognition task, it was maximal over central electrodes (see Fig. 6). As can be seen in Table 2, no other effects were significant in this time window.

The ERPs recorded in the old/new-recognition task were characterised by a late negative-going old/new effect as well. The results from the ANOVAs using data in the 1200–1800 ms interval revealed that this effect was reliable for perceived items, and that it increased in magnitude over posterior recording sites. A corresponding effect was marginally significant for imagined items when the analysis was conducted on data from lateral electrodes [$F(1, 15) = 4.20$, $P < 0.06$]. Differences between the old/new effects for perceived and imagined items were evident in an interaction between type and electrode position. Whereas the negative difference between old/new items was evenly distributed across the lateral recording sites for imagined items, it increased over posterior electrodes for perceived items.

Because of the marginal reliability of the positive-going old/new effect associated with perceived items and of the negative-going old/new effect for imagined items, the results of topographical analyses were considered to be of minor interest, and were therefore, not conducted.

In agreement with the results found in the reality-monitoring task, onset-latency estimates suggest that a reliable difference between old/new items appeared slightly earlier for imagined compared with perceived stimuli. The estimated onset of the old/new effects were for perceived items 476 ms (at Cz), and for imagined items 412 ms (at Fz) (see Fig. 7). This outcome should, however, be treated with caution, because it involves a small old/new effect for perceived items. However, it should be noted that the choice of relatively wide time windows may be a reason for the marginal reliability of perceived items, and narrower window could possibly pinpoint effects of statistical significance. In keeping with the procedure used for the reality-monitoring task, mean onset-latency values were computed across additional electrodes. The number of electrodes satisfying the fairly stringent criterion of significant t-values during 100 ms was reduced to 3. The difference between old items still remained with 522 ms for perceived items and 421 ms for imagined (perceived: Cz, P3, T5; imagined: Fpz, Fz, Cz,). The test for statistical significance used the same procedure as for the reality-monitoring task and showed a slight tendency for the pattern imagined < perceived at central sites,

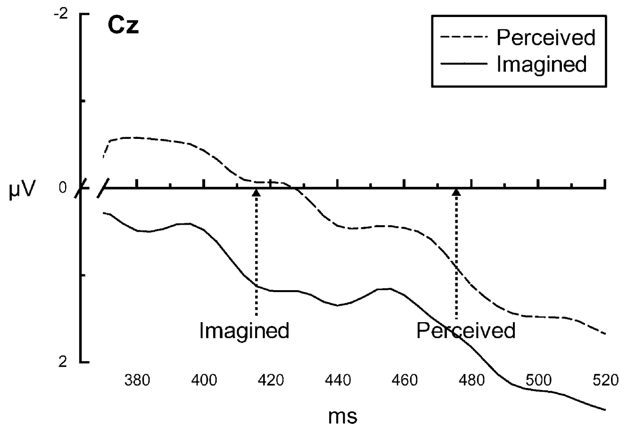

Fig. 7. Difference waveforms (i.e. old − new) shown for perceived and imagined items at Cz in the old/new-recognition task. The vertical arrows depict the estimated onset-latencies for perceived (476 ms) and imagined items (416 ms).

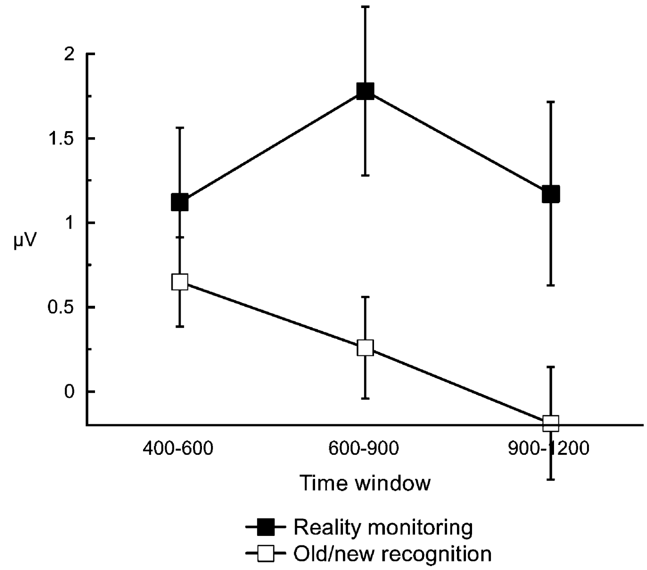

Fig. 8. Mean old/new effects at prefrontal electrodes (Fp1, Fpz, and Fp2) in the first three time windows. Amplitudes are collapsed across item type and site, and displayed separately for the two memory tasks. Vertical lines depict standard errors of the means.

$t(12) = 1.87$, $P < 0.09$. No other effects reached the level of significance.

3.2.2. Across-task analyses

The following analyses were aimed at revealing whether any task-related difference was evident in the old/new effects. To this end, difference scores were computed by subtracting the amplitude of new items from old items, yielding separate measures that represented the old/new effect for perceived and imagined items. Only effects involving the factor of task are reported below.

An initial ANOVA with the factors of time window (400–600 ms versus 600–900 ms versus 900–1200 ms), type (perceived versus imagined), recording site (all 17), and task (reality-monitoring versus old/new-recognition) was conducted to contrast the widespread positive-going old/new effects across-task over the time windows that encompassed the effects. However, no effect involving the factor of task was found to be reliable (main effect: $F = 1.00$, NS; interactions: maximum $F = 2.05$, NS). Since previous research that has directly compared the old/new effect in item and source-memory tasks (e.g. [62,69]) has reported task-related differences at prefrontal sites, planned comparisons were performed over these regions. The analysis used the same factor as above, but the recording sites were restricted to Fp1, Fpz, and Fp2. The outcome of the ANOVA revealed a marginally significant main effect of task [$F(1, 30) = 3.80$, $P = 0.06$] and a significant interaction between task and time window [$F(1.87, 55.96) = 3.68$, $P < 0.05$]. As suggested by Fig. 8, the prefrontal old/new effect was reliable from 400 to 1200 ms in the reality-monitoring task, but only in the initial time window in the old/new-recognition task. Follow up ANOVAs confirmed that reliable differences between memory tasks existed in the 600–900 ms [$F(1, 30) = 4.72$, $P < 0.05$] and in the 900–1200 ms time windows [$F(1, 30) = 4.54$, $P = 0.05$]. A similar analysis for the frontal sites (F3, Fz, and F4) gave rise to an interaction between time, type, site, and task [$F(3.27, 98.13) = 3.68$, $P < 0.05$]. This did, however, not reflect any magnitude differences between memory tasks, but rather the fact that the old/new effect for imagined items tended to change from a left-medial maximum to a right-medial maximum later on in the epoch in the old/new-recognition task. Thus, compared with old/new-recognition, reality-monitoring was associated with a prefrontal old/new effect that was greater in magnitude and considerably more sustained over time. This finding may reflect an equal magnitude of the early frontal old/new effect in the two tasks and a greater late frontal effect in the source-retrieval task. However, it should be noted that these two effects are usually observed at F3, Fz, and F4, sites that did not show the same pattern of effects as the prefrontal sites.

In addition, re-scaled data were used to compare the scalp-distributions of the old/new effects in the time windows that showed reliable effects for both tasks (perceived: 1200–1800 ms; imagined: 400–600, 600–900, 900–1200 ms). No task × site interaction was observed for perceived items, indicating that the late negative-going effect was similarly distributed in the reality-monitoring task and the old/new-recognition task ($F < 1$, NS). In contrast, an interaction between task and site was revealed in the 900–1200 ms time window for imagined items [$F(2.69, 80.74) = 2.82$, $P = 0.05$]. As was evident in the within-task analyses, the old/new effect was right-frontally distributed in the reality-monitoring task, whereas it displayed a more central distribution in the old/new-recognition task. In addition, the interaction reflected the differential involvement of the late negative wave in the two tasks (see

Figs. 3 and 6). However, interpretation is hampered by the fact that the only old/new effects found reliable in this time window were those observed over the right hemisphere.

4. Discussion

As expected, the participants' ability to discriminate between old/new items exhibited high levels of accuracy, and furthermore, no differences were found when contrasting the previously perceived and imagined items on this measure. However, old/new-discrimination was slightly higher in the reality-monitoring task than in the old/new-recognition task. One possible explanation for this effect is that the reality-monitoring task encouraged participants to scrutinise the content of their memories more thoroughly, allowing more time for relevant information to be taken into account, and at the same time lowering the number of false alarms prompted by a feeling of familiarity. Further support for this line of argument comes from the reaction time measures. Correct "old" judgements were associated with slower reaction times in the reality-monitoring task compared with those observed in the old/new-recognition task (466 ms). This finding parallels the results of previous studies that have used a similar test procedure and supports the notion that additional processing time is needed to retrieve source-specifying information about recognised items (e.g. [62,69]). Nevertheless, it should be noted that participants in the reality-monitoring task were required to make a three-way decision while a binary decision was sufficient in the old/new-recognition task. But, because of the comparable reaction times to correct rejections in the two tasks, this alternative explanation seems unlikely. A further possibility is that the source discrimination response, because made with two fingers on the same hand could give rise to the prolonged reaction times. However, Senkfor and Van Petten ([62], Experiment 2) compared a binary item-memory test with a binary source-memory test (only old items were displayed as test probes) and observed comparably longer reaction times in the source task. Thus, it seems unlikely that the observed difference is merely a reflection of motor-related response-selection processes. Consistent with the SMF, while a general feeling of familiarity is sufficient for merely indicating whether a test word is repeated or not, a greater amount, or a different type, of information is required for correct source-attribution. However, it should be noted that the observed pattern of effects is readily explained by the dual-process account as well, arguing that reality-monitoring draws more extensively on time-consuming systematic memory retrieval than old/new-recognition.

Interestingly, for our purposes, no difference in reaction times was observed between perceived and imagined items in either memory task. That is, these measures did not offer data that would lend support to the notion that different types of information revive at different rates. However, as will be discussed below, a difference was found between the onset-latencies of the ERP-old/new effects for perceived and imagined items.

Participants were highly accurate in identifying the source of perceived and imagined items. A measure of source-attribution accuracy was nearly error-free. Therefore, the context of the present experiment permitted ERPs elicited by correctly judged perceived and imagined items to be examined across trials on which the probability of recollection (i.e. source-specifying information) was as high as possible and the number of correct guesses was minimised for both item types. First, this means that a potential difference in response probability and/or response confidence associated with perceived and imagined items can be ruled out as a factor causing the differences observed in the ERPs, and second, that differences in ERP magnitude do not merely reflect a diluted old/new effect for one type of old items associated with lower memory performance. In light of this, we next discuss the results of the analyses of the ERP data.

In accordance with previous ERP studies of memory, old items were associated with more positive-going ERPs than were correctly rejected new items. This difference took the form of a widespread old/new effect that began approximately 400 ms post-stimulus-onset and lasted about 600 ms at most sites and somewhat longer over prefrontal regions. Initially, bilaterally distributed across the scalp, the effect exhibited a right anterior distribution later on in the epoch. The effect was reliable for both perceived and imagined items in the reality-monitoring task, for imagined items in the old/new-recognition task, and marginally so for perceived items in the old/new-recognition task.

The SMF claims that the types of information that are characteristic of different sources and used for source-monitoring decisions, revive and become available at different rates. Support for such a proposal is given if the time-courses of the ERP-old/new effects for perceived and imagined items differ. The present findings add weight to this suggestion in that the old/new effects for perceived and imagined items did show different onset-latencies. Furthermore, this difference consisted of an earlier onset of the old/new effect for imagined items than for perceived items, a pattern of results in agreement with the behavioural results reported by Johnson et al. [30]. As noted above, an analogous difference was not evident in the reaction time data. Of course, the fact that one type of information revives and becomes available at an earlier point in time does not necessarily entail that the sufficient information for a memory judgement is also available at an earlier point in time. However, because the results of the response-signal procedure in Johnson et al. do in fact suggest this to be the case, we will attempt to give another possible reason for the disparity between the reaction time data and the onset-latencies observed in the present experiment. One interpretation of the observed pattern is that the early ERP measures tap, the same early memory processes as those assessed by the response-signal procedure. However, the unconstrained response interval used here promotes additional evaluation processes that may obfuscate the early latency effects. In the present context, this would imply that the early ERP measures are sensitive to the perceived/imagined dimension in showing faster reactivity to previously imagined items, but this is offset by another difference in the length of ensuing evaluative processes, because memories of imagined events are associated with greater amounts of retrieved information. Whatever the nature of the processes underlying the reaction times, the present ERP findings support the notion, stemming from the SMF, that records of cognitive operations performed during imagery revive and become available to source-monitoring mechanisms earlier than records of perceptual detail.

Interestingly, the onset difference was observed only at frontal sites, and it may indicate variation in onset of the early frontal old/new effect. As described in Section 1, previous research has linked this effect to the familiarity component of recognition memory [14,15,39,41,56] in part by demonstrating its insensitivity to manipulations such as depth of processing [56]. With respect to the equal magnitude of the old/new effects associated with perceived and imagined items in the early time window, the present findings are in accord with this proposal. In addition, it may tentatively be argued that the latency of the early frontal old/new effect may have been shortened following the imagery task due to quickened access to conceptual information. Furthermore, it should be noted that the onset difference was more apparent in the source-retrieval task than in the item-recognition task. The reason for this is not clear. Speculatively, the early ERP measures may reflect access to information that differs in some respect (e.g. amount of conceptual information) for the two sources, and these differences may, therefore, be more important for the source judgement than for the old/new judgement.

The main difference between the two types of old items was that the late widespread old/new effect was significantly greater for imagined than for perceived items. While the waveforms for both types of old items initially deviated from correct rejections to the same degree, imagined items showed a more pronounced positivity later on in the epoch. Although the observed old/new effect was widespread across the scalp (and clearly evident at parietal sites), it continued to show an anterior maximum and not the typically posterior maximum. However, the present experiment departs from a number of previous studies in the memory task requirements. Critically, recollection of the prior presentation of the test probe would not be sufficient for accurate performance in the reality-monitoring task. Rather, participants had to recollect what occurred after the prior presentation of the word and decide whether a picture was displayed or if they were instructed to mentally visualise an image. It is possible that anterior regions are involved in trying to retrieve this part of the study trial.

The findings show that the widespread old/new effect, despite equal memory performance, is sensitive to an item's study context. In what relevant way do these two types of old items differ? Well-known findings in the memory research literature are that items processed at a deeper level [13]; self-generated material [64]; or subject-performed tasks [12], are better remembered than material encoded with less effort. Analogously, the encoding manipulation used in the present study comprised encoding of items in two different ways, one that required participants to mentally visualise images of objects, and another that simply required participants to look at presented pictures of objects in a more passive manner. Although this manipulation did not affect participants' memory performance, presumably because of the overall high level of accuracy, it seems plausible to assume that imagined items contain a larger amount of potential retrieval cues established during encoding than perceived items. The present findings, therefore, offer support for the proposal put forward in previous studies [51,72,75] that the old/new effect is sensitive to the quality or amount of contextual information retrieved from memory. However, for reasons discussed above, a prerequisite for such an explanation is that the compared ERP averages do not include an unequal proportion of trials on which recollection was missing (e.g. correct responses based on guessing) [74,75]. This alternative way of interpreting differences in magnitude would entail that both classes of old items show positive-going deflections of the same size, but that the positivity is attenuated for one of the classes. Since the present experimental conditions promoted memory judgements based on recollection for both perceived and imagined items, this alternative explanation seems highly unlikely. While the suggested interpretation of the ERP-old/new effects is consistent with the claim of the SMF that source-memory (or recollection) may be described in a graded fashion, depending on the amount and quality of the information retrieved, it is important to note that this conclusion is not incompatible with dual-process accounts of recognition memory.

The old/new effects observed in the present study did not, however, exhibit the left > right asymmetry over parietal regions typically found in ERP studies of memory. There are a number of possible reasons for this lack of asymmetry. For example, the distribution of the effect may be affected by the type of stimuli used (but see [61]). Another possibility is that the choice of reference used in the present experiment (linked earlobes) may have had an attenuating effect on posterior asymmetries [16]. However, a similarly widespread and bilateral old/new effect as that reported here has been evident in previous studies that have used the linked mastoid reference (e.g. [69]). Further, it may be that the effect was attenuated by the evolvement of the temporally overlapping late negative-going wave. As the earlier positive-going effect, this negative wave differentiated between old/new items and was, furthermore, most prominent over the left posterior scalp regions. Consequently, the left > right asymmetry may have been levelled out when the two effects were summated. Likewise, the right-frontal effect has been observed for longer durations than is evident in the present data and the negative slow wave may have had an attenuating impact on this effect as well. Alternatively, the duration of the effect may be related to the memory task, which was easier than tasks in previous studies.

The negative-going effect was apparent from approximately 1000 ms post-stimulus-onset and tended to continue throughout the recording epoch at most sites. A difference in magnitude was observed, indicating a greater effect for perceived items than for imagined. Although a similar, but not always left-sided, negative-going effect has been reported in previous studies of source-memory [14,58,74,76] and associative recall [57], the functional significance of the effect remains unclear. Since the amplitude of this negative-going slow wave has been found to grow larger with increasing reaction time of both studied and unstudied items, it has been claimed to reflect response-related rather than mnemonic processes [76]. Support for this line of argument can be found in the present results as well, as the negative-going old/new effect tended to be more prominent in the reality-monitoring task than in the old/new-recognition task and the reaction times to hits were significantly longer in the former task. However, following this reasoning, the magnitude difference in the effect for perceived and imagined items should lead us to expect a difference in reaction times between the two types of old items. This was not found, however. Similarly, while there was no task-related difference in the reaction times to correct rejections, reality-monitoring was associated with a larger negative-going wave than old/new-recognition. Relating ERP and fMRI data, Nessler et al. [43] linked a similar negative slow wave to activation in anterior cingulate cortex (ACC). Activations in ACC have been observed in a number of studies of episodic retrieval and are considered to reflect attentional processes responsible for initiating and/or suppressing responses, and are thus, prominent under conditions of response competition [10]. Assuming that the negative-going wave in the present study reflects varying levels of response competition, it might be interesting to note the magnitude difference between perceived and imagined items. Since no apparent difference in response procedures existed for the two source judgements, increased response competition presumably arose from factors other than motor-related response-selection processes. However, further studies are needed in order to elucidate the factors modulating the observed negative-going wave.

While reliable differences in magnitude were observed between perceived and imagined items, the topographical analyses revealed no evidence of any differences in scalp-distribution as a function of encoding condition. Similarly, a recent study by Allan et al. [1] reported that no topographical differences were evident in ERP cued recall effects as a function of encoding condition (Experiment 1: shallow versus deep; Experiment 2: auditory versus visual). The lack of a difference suggests that the processes supporting source-memory for perceived and imagined items are neurally and functionally equivalent, and that they differ instead in the level of their engagement. Although this may be the case, it should be noted that the null result could arise from a number of reasons. First, it may be that greater statistical power is required to reveal scalp-distribution differences than was present in the experiment reported here. Second, it is possible that non-equivalent processes do promote accurate source-memory for perceived and imagined items, although these processes are inaccessible to electrophysiological measures taken at the scalp. Third, participants in the present experiment may have made their judgements by setting a criterion along a single dimension (i.e. presence/absence of perceptual detail, or presence/absence of records of cognitive operations). For example, since the two encoding conditions used here were both visually oriented (i.e. look at pictures versus mentally visualise images), records of associations and of the generation procedure might have been more diagnostic than perceptual detail in this particular task (see, e.g. [8] for a similar line of argument). If this was the case, quantitative rather than qualitative differences between the old/new effects for perceived and imagined items would be expected.

The direct comparison of the positive-going old/new effect for the two memory tasks across prefrontal scalp regions provided results that add to previous findings suggesting that these areas are differentially involved in memory tasks that vary in their requirement to remember contextual information about the study episode [62,69]. The results from a number of neuroimaging studies converge and link activation in the prefrontal cortex, particularly, in the right hemisphere, to episodic retrieval (see [9,10,19] for reviews). Several processes have been suggested to account for this activation, such as establishing and maintaining a retrieval mode [45], engaging in retrieval effort [59], and verifying and monitoring the products of successful memory retrieval [54]. Because of the high levels of memory performance, the results of the present study offer no further evidence to differentiate between these alternatives.

To recapitulate, we set out to examine whether behavioural data and ERP memory effects would provide support for the interpretations of Johnson et al. [30]. The results are consistent with the proposal that reality-monitoring and old/new-discrimination vary in their differentiation requirements, and moreover, that different types of source-specifying information revive at different rates. However, analyses of the scalp-distributions of the old/new effects failed to show support for the notion that neurally and functionally distinct processes support accurate source-memory for perceived and imagined items. Furthermore, the present findings add weight to the view that the widespread ERP-old/new effect reflects the quality or amount of information retrieved from memory and to the notion that the prefrontal old/new effect reflects processes that are differentially engaged in item and source-memory tasks.

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