The influence of response–time demands on electrophysiological correlates of successful episodic retrieval

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Abstract

Event-related potentials (ERPs) were acquired in two memory retrieval tasks. In Experiment 1 a 2.5 s response–time limit was imposed at test, while in Experiment 2 there was no explicit upper limit. There were no other structural differences between the two experiments. The response–time manipulation did not influence the accuracy of memory judgements, but resulted in qualitative changes in the ERP old/new effects that were elicited in the two tasks. In Experiment 2, the ERP old/new effects from 700 ms post-stimulus onwards comprised a relatively greater positivity for correct judgements to old items in comparison to correct judgements to new items. In keeping with findings in previous studies, this relative positivity was largest at anterior sites over the right hemisphere. In Experiment 1, by contrast, the ERP old/new effects during the same time window were most prominent at right hemisphere central electrode locations, and comprised a relatively greater positivity for correct judgements to new rather than to old test items. In combination, the findings in the two experiments are consistent with the view that the imposition of different response–time demands results in the engagement of neurally and functionally distinct processes during episodic retrieval. The time course of these distinct ERP old/new effects suggests that different post-retrieval monitoring operations were engaged according to the time available to make memory judgements.

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1. Introduction

Event-related potentials (ERPs) index processes that are engaged during retrieval of information from episodic memory (for recent reviews, see [6,9,26]). By far the most common way in which electrophysiological indices of episodic retrieval processing have been studied is via the analysis of ERP old/new effects. These are the differences between the scalp-recorded neural activity that is elicited by old (previously studied) and new items to which correct old/new judgements (and variants thereon) have been made. There is a family of ERP old/new effects that can be fractionated on the basis of a combination of several sources of evidence [9]. These include the time courses of the ERP old/new effects, their scalp distributions, and their sensitivity to experimental variables [42].

One ERP old/new effect that is commonly evoked when participants are asked to recover contextual (or source) information about a prior study episode is largest at right hemisphere anterior electrode locations, and has been linked to control processes that are engaged during and/or after retrieval [9,31,37,39]. This right-frontal ERP old/new effect comprises a relatively greater positivity for old items attracting correct context judgements than for new items attracting correct judgements. The effect onsets approximately 500–700 ms post-stimulus and can continue for at least a further 1500 ms (e.g. [34]). This anteriorly distributed old/new effect is evident in the vast majority of studies in which an explicit context judgement has been required of participants (for example, see [7,25,37,40]), and it is of considerable interest, therefore, that in three recent studies the effect has not been evident, possibly overlaid by other modulations of the electrical record [3,4,8].
In one of these studies, Cycowicz et al. [4] recorded ERPs during the test phase of the recognition memory exclusion task [13,14], following an encoding phase in which line-drawings of nameable objects were presented in one of two colours (red or green). All drawings were presented in the same colour (black) at test, and participants were asked to make an ‘old’ response only to objects that had been presented in one of the two colours (targets), and a ‘new’ response to unstudied pictures as well as to objects shown in the alternate colour (non-targets). In the study of Dywan et al. [8], the task required old/new recognition, but some unstudied words were repeated during the test phase. Participants were instructed to respond ‘old’ only to words that had been encountered at study. This procedure bears some similarity to the retrieval phase of the exclusion task if unstudied repeated items are regarded as non-targets.

Common to these two studies was a greater relative negativity associated with correctly identified targets and non-targets than with correctly identified new items. This relative negativity onset approximately 700 ms post-stimulus and was evident at the majority of scalp locations, with a tendency to be most pronounced at central and posterior electrodes and was evident at the majority of scalp locations, with a relative negativity onset approximately 700 ms post-stimu-

lus and was evident at the majority of scalp locations, with a tendency to be most pronounced at central and posterior electrode sites over both the right and the left hemispheres. In another study [3], Cycowicz et al. replicated their earlier findings for the exclusion task [4], and also reported that morphologically similar old/new effects were elicited when a speeded old/new judgement preceded the red/green judgement. These findings contrast markedly with those in other ERP studies in which retrieval of context information has been required, and perhaps most notably with those of Wilding and Rugg [41], who obtained a reliable right-frontal ERP old/new effect for correct judgements to targets in the exclusion task when the context discrimination was made on the basis of speaker gender.

One explanation for these disparate findings is that ERP old/new effects are modulated according to the kind of information that is required for a context judgement. In keeping with this possibility, the ERP studies of Cycowicz et al. are, to our knowledge, the only ones in which discrimination on the basis of colour information has been required, and perhaps most notably with those of Wilding and Rugg [41], who obtained a reliable right-frontal ERP old/new effect for correct judgements to targets in the exclusion task when the context discrimination was made on the basis of speaker gender.

If this possibility is correct, then the data of Cycowicz et al. are particularly important, since there is little direct evidence to date that ERP old/new effects are sensitive to the content of information that is retrieved from memory (in particular, see [2,6]), and thus provide little support for the ‘consensus’ account of episodic retrieval, according to which retrieval involves recapitulation of activity in the same regions that were engaged at the time of encoding [5,23,24,33]. However, the surface correspondence—albeit based on visual inspection only—between the findings of Cycowicz et al. [3,4] and those of Dywan et al. [8] challenges the account that Cycowicz et al. offer, since the tasks entailed retrieval of distinct kinds of information; colour in the case of Cycowicz et al., and temporal order/recency in the case of Dywan et al.

This correspondence raises the possibility that the parieto-central negativities in the three studies have a common antecedent, and one design feature that distinguishes them from other ERP studies is the relatively short time period in which participants were asked to make a response. In the studies of Cycowicz et al. [3,4], the maximum time available for the first memory judgement was fixed at 2 s, while in the study of Dywan et al. the time varied between 3 and 4 s on a trial-by-trial basis [8]. It is reasonable to assume that this is effectively 3 s as participants were not aware of the response cut-off in advance of each trial. In the majority of ERP studies of episodic retrieval, longer response intervals have been employed [31,32], and in a number of studies there was no explicit limit, with progression to the next trial contingent upon the response of the participant (e.g. [28,30,38,41]).

There are good reasons, furthermore, to assume that response–time requirements will influence retrieval processing. For example, Johnson et al. employed a response deadline procedure and demonstrated that different kinds of contextual information revive and become available at different rates [20], while Johansson et al. reported electrophysiological evidence that was consistent with this view [17]. Johnson et al. [20] interpreted their results within the source monitoring framework (SMF: [18,19]), according to which context or source judgements are made on the basis of different kinds of information and different evaluative processes, the engagement of which is determined by task demands. These demands almost certainly include response–time requirements.

The issue here, then, is the specificity of the retrieval processes that are indexed by the ERP old/new effects in the studies of Cycowicz et al. [3,4] and Dywan et al. [8]. An important question is whether the centro-parietal old/new effects observed by Cycowicz et al. do in fact index colour-specific retrieval processing, or whether, as the correspondence with the data of Dywan et al. suggests, the effects index processes engaged during retrieval tasks that are associated with the imposition of relatively short response deadlines but are blind to the content of information that is to be retrieved.

In order to distinguish between these possibilities, ERPs were recorded during the retrieval phases of two exclusion tasks that differed only in their response–time requirements. In both experiments speaker gender at encoding was the context manipulation. In Experiment 1, the maximum time in which a response could be made was 2.5 s on each retrieval trial. In Experiment 2, the response requirements matched those used by Wilding and Rugg [41] in their previous ERP exclusion experiment: there was no explicit upper limit for responses although participants were encouraged to balance speed and accuracy of responding equally.
The expected outcome in Experiment 2 is a replication of the findings of Wilding and Rugg [41]. If the ERP old/new effects in Experiment 1 correspond with those in Experiment 2, then response time demands alone cannot explain the disparities between the old/new effects reported by Cycowicz et al. and Dywan et al. [3,4,8] and those in a number of previous studies [9]. If, however, there is a correspondence between the findings in Experiment 1 and those of Cycowicz et al. as well as Dywan et al., then it would seem that limiting the time available to make memory judgements influences ERP old/new effects in a way that is independent of other retrieval demands, including the content of the information that is to be retrieved.

2. Materials and methods

Because of the similarities between the two experiments, they are described jointly.

2.1. Participants

Twenty participants (10 male, mean age = 20 years, 1 month) took part in Experiment 1. The data from two participants (one male) was discarded due to the fact that insufficient trials (for criteria see below) contributed to at least one experimental condition of interest because the participants were unable to restrict eye-blinks in accordance with the task instructions (see below). Eighteen participants (nine male, mean age = 20 years, 4 months) took part in Experiment 2. No participant took part in both experiments. Three participants in Experiment 1 were left-handed1. All remaining participants were right-handed as assessed by writing-hand, and all participants were native English speakers. Each participant gave informed consent before completing the task.

2.2. Materials

Three hundred and sixty low frequency words (range 1–7 per million) were selected from the Kucera and Francis corpus [21]. All words were open-class and ranged between four and nine letters in length. Words were spoken in the study phases of the experiments, and presented visually in the test phases. The auditory stimuli were presented binaurally through headphones at a comfortable hearing level. They were digitised at 22 kHz with 16-bit resolution, and were edited so that the onset of the stored sound segment corresponded with the onset of the spoken word. The mean duration of these stimuli was 660 ms (male voice) and 630 ms (female voice). Test words were presented in central vision on a PC monitor in black letters on a white background. The visual stimuli subtended maximum visual angles of 2.2° (horizontal) and 0.7° (vertical).

2.3. Design and procedure

The complete list of 360 selected words was divided randomly into eight shorter (45-word) lists. Each list comprised the stimuli to be used in one of eight study-test cycles, and each was separated into three 15-word sub-lists. Words on one sub-list were spoken in the female voice at study and words on another were spoken in the male voice. The remaining sub-list comprised new words presented at test only. Within each study-test cycle, therefore, 30 words (15 male/female voice) were spoken at study, and 45 words (30 old, 15 new) were shown at test. The study and test stimuli so defined comprised one complete task list. Two further task lists were constructed by rotating within each shorter (45-word) list the words to be spoken by one of the two voices at study, and those to be presented at test only. Thus across lists all words were designated as either old or new, and were spoken in the male/female voice. In each of the three complete task lists, the order of presentation of the eight study-test cycles differed in order to control partially for order effects. Finally, the order of word presentation at both study and test within each study-test cycle was determined randomly for each participant. Each study and test phase began with one filler word. In total, each participant heard 248 words at study and saw 368 words at test.

Each participant completed one task list. Each study trial began with a fixation asterisk that was presented for 1000 ms. A blank interval of 100 ms intervened between the offset of the fixation cue and the onset of the spoken word. One thousand and five hundred milliseconds after the onset of the word, the instruction ‘BLINK AND SPEAK NOW’ was displayed for 2000 ms. Participants were informed that they should attempt to restrict their eye blinks to the period during which this cue was visible, and also to repeat aloud the spoken word as well as state the gender of the speaker. A blank interval of 1000 ms ensued before the reappearance of the asterisk signalling the start of the next trial.

An interval of approximately 1 min intervened between each study and test phase, during which participants were informed of the response requirements in the test phase. Each test trial began with a fixation asterisk that was present on the screen for 500 ms. A period of 100 ms intervened between the offset of the fixation cue and the onset of each test word, which was visible for 300 ms. In Experiment 1, the cue ‘BLINK NOW’ appeared on the screen 2500 ms after the onset of the test stimulus irrespective of whether or when participants made a response. In Experiment 2 there was no upper limit on response times, and a fixed interval of 2000 ms intervened between the response and the onset of the blink cue. In both experiments, participants were asked to restrict their eye blinks and eye movements to the period in which the blink instruction was visible. This cue remained on the screen for 2000 ms and an interval of

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1 The ERP old/new effects of these participants did not differ qualitatively from those of the right-handed participants.
were located according to the 10–20 system [15] and des, 25 of which were housed in an elastic cap. The sites when responding.

In Experiment 2, participants were instructed simply to balance speed and accuracy equally of the blink instruction. In Experiment 2, participants were told that they had a maximum of 2.5 s in which to make their responses at test and experiment: participants were asked to respond with one hand to targets and the other to non-targets, and were informed of the target/ non-target designation for each test phase only after completing the preceding study phase. The hand used for responses to targets was balanced across participants. In Experiment 1 participants were told that they had a maximum of 2.5 s in which to make their responses at test and that the end of this period corresponded with the appearance of the blink instruction. In Experiment 2, participants were instructed simply to balance speed and accuracy equally when responding.

2.4. EEG recording procedure

EEG was recorded from 26 silver/silver chloride electrodes, 25 of which were housed in an elastic cap. The sites were located according to the 10–20 system [15] and comprised midline (Fz, Cz, Pz) as well as left (Fp1, F7, F5, F3, T3, C5, C3, T5, P5, P3, O1) and right (Fp2, F8, F6, F4, T4, C6, C4, T6, P6, P4, O2) hemisphere locations. Two additional electrodes were placed on the right and left mastoid processes. EEG was recorded continuously at 166 Hz (6 ms per point) with Cz as the reference electrode, and was re-referenced computationally off-line to a linked mastoid reference into epochs of 1536 ms (256 data points), each including a 102 ms pre-stimulus baseline relative to which all post-stimulus amplitudes were measured. The data from Cz was reclaimed. EOG was recorded bipolarly from electrodes situated on the outer canthus and above the supraorbital ridge of the left eye. EEG and EOG were recorded with a bandwidth of 0.03–40 Hz (−3 dB). Trials containing eye-blinks were rejected according to a criterion set individually for each participant. Trials on which A/D saturation or baseline drift (difference between first and last data point) exceeded ±80 μV were also rejected.

Averaged ERPs were formed for correct judgements to targets, non-targets and new words for each participant in each experiment. Participants were excluded if they did not contribute at least 16 artefact-free trials to each condition, in keeping with the approach taken in previous studies [39,43]. The ERP data were collapsed across the factor of voice, on the basis of null results for this factor in preliminary analyses (replicating the findings in previous studies [31,39,41]). In Experiment 1 the mean numbers of trials per condition were 63, 68 and 86 for correct responses to targets, non-targets and new words, respectively. The equivalent values in Experiment 2 were 61, 63 and 83. The averaged ERPs for each participant and for each condition of interest were subjected to a 7-point binomially weighted smoothing filter prior to analysis.

3. Results

3.1. Behavioural data

Table 1 shows the mean probabilities of, and reaction times (RTs) for, correct responses to targets, non-targets and new words in experiments 1 and 2. As for the ERP data, and for the same reason, the means are collapsed across the factor of study voice. Hereafter, correct responses to targets and non-targets will be referred to as target hits and non-target hits, respectively. The term old words will refer to targets and non-targets jointly.

In each experiment, the probabilities of a target hit were reliably greater than the probabilities of a target response to a non-target (Experiment 1: t(17) = 11.54, P < 0.001; Experiment 2: t(17) = 8.55, P < 0.001) or a new word (Experiment 1: t(17) = 21.52, P < 0.001; Experiment 2: t(17) = 13.20, P < 0.001). Separate ANOVAs on the accuracy and RT data included the factors of experiment and word status. Accuracy varied according to word status only (F(1,80.7) = 67.56, P < 0.001), and post hoc analyses revealed that, while not differing from each other, the probabilities of correct responses to old words were reliably lower than those to new words (Newman–Keuls, all P < 0.01). RTs were slower in Experiment 2 than in Experiment 1 (F(1,34) = 9.93, P < 0.01), and also varied according to word status (F(1.5, 50.9) = 33.44, P < 0.001). The only differences revealed by post hoc analyses were that RTs were reliably faster for correct judgements to new rather than to old words (all P < 0.01).

Table 1

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Target</th>
<th>Non-target</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P (correct)</td>
<td>P (correct)</td>
<td>P (correct)</td>
</tr>
<tr>
<td></td>
<td>RT</td>
<td>RT</td>
<td>RT</td>
</tr>
<tr>
<td>Experiment 1</td>
<td>0.70 (0.11)</td>
<td>0.77 (0.10)</td>
<td>0.95 (0.06)</td>
</tr>
<tr>
<td></td>
<td>1107 (150)</td>
<td>1140 (142)</td>
<td>982 (162)</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>0.73 (0.15)</td>
<td>0.78 (0.13)</td>
<td>0.91 (0.10)</td>
</tr>
<tr>
<td></td>
<td>1314 (297)</td>
<td>1374 (246)</td>
<td>1135 (204)</td>
</tr>
</tbody>
</table>

S.D.s in brackets.
3.2. ERP data

The ERPs associated with correct judgements to targets, non-targets and new words are shown in Figs. 1 and 2. In both experiments, the ERPs evoked by old words are more positive than those evoked by new words from ~300 to 700 ms post-stimulus. At posterior electrode locations this relative positivity is greater over the left than the right hemisphere, and during this period the ERPs elicited by targets are relatively more positive than those elicited by non-targets. The principal divergences between the ERPs across experiments occur from ~700 ms onwards. In Experiment 1, the ERPs evoked by correct judgements to new words are relatively more-positive-going than those evoked by correct judgements to old words, most markedly at right-central electrodes. In Experiment 2, the ERPs evoked by old words are relatively more positive-going than those evoked by new words, with this relative positivity restricted to right-frontal electrodes.

The initial analyses of the ERPs were conducted using data from the nine electrodes shown in Figs. 1 and 2 (F5, Fz, F6, C5, Cz, C6, P5, Pz, P6). These form a 3 x 3 grid covering midline and lateral locations at anterior, central and posterior scalp sites. The analyses incorporated the factors of location in the anterior/posterior (AP: anterior, central, posterior) and left-right (LR: left-hemisphere, midline, right-hemisphere) planes. They were conducted separately for each experiment in order to determine the correspondence between the ERP old/new effects in these experiments and those reported in previous studies, as well
Table 2
Results of the paired contrasts between ERPs evoked by correct judgements to targets (T), non-targets (NT) and New words in experiments 1 and 2 over the 400–700 and 700–1300 ms epochs, respectively

<table>
<thead>
<tr>
<th>Effect</th>
<th>df</th>
<th>Contrast</th>
<th>T vs. NT</th>
<th>T vs. New</th>
<th>NT vs. New</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>F</td>
<td>ε</td>
<td>F</td>
</tr>
<tr>
<td>Experiment 1: 400–700 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>1,17</td>
<td>9.30***</td>
<td>19.72***</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>CN × AP</td>
<td>2,34</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>CN × LR</td>
<td>1,17</td>
<td>8.74**</td>
<td>0.68</td>
<td>8.74**</td>
<td>0.84</td>
</tr>
<tr>
<td>CN × AP × LR</td>
<td>2,34</td>
<td>9.58*</td>
<td>0.67</td>
<td>4.07*</td>
<td>0.70</td>
</tr>
<tr>
<td>Experiment 2: 400–700 ms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>1,17</td>
<td>6.09*</td>
<td>64.45***</td>
<td>19.07***</td>
<td></td>
</tr>
<tr>
<td>CN × AP</td>
<td>2,34</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>CN × LR</td>
<td>1,17</td>
<td>4.68*</td>
<td>0.99</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>CN × AP × LR</td>
<td>2,34</td>
<td>7.03*</td>
<td>0.74</td>
<td>0.73</td>
<td></td>
</tr>
<tr>
<td>Experiment 1: 700–1300 ms</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CN</td>
<td>1,17</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>CN × AP</td>
<td>2,34</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>CN × LR</td>
<td>1,17</td>
<td>6.22*</td>
<td>0.71</td>
<td>9.01**</td>
<td>0.90</td>
</tr>
<tr>
<td>CN × AP × LR</td>
<td>2,34</td>
<td>5.52**</td>
<td>0.56</td>
<td>5.29**</td>
<td>0.79</td>
</tr>
<tr>
<td>Experiment 2: 700–1300 ms</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CN</td>
<td>1,17</td>
<td>ns</td>
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<tr>
<td>CN × AP</td>
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<tr>
<td>CN × LR</td>
<td>1,17</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>CN × AP × LR</td>
<td>2,34</td>
<td>5.43**</td>
<td>0.75</td>
<td>3.38*</td>
<td>0.90</td>
</tr>
</tbody>
</table>

CN, condition; AP, anterior/central/posterior; LR, left/midline/right. * P < 0.05, ** P < 0.01, *** P < 0.001, ε, epsilon correction.

as to license subsequent between-experiment analyses. They were conducted over the 400–700 and 700–1300 ms time-windows, selected in order to encompass the epochs in which ERP old/new effects have been reported previously, as well as to capture the differences between experiments that are evident in Figs. 1 and 2. The analyses comprised all possible paired contrasts of the ERPs associated with correct judgements to targets, non-targets and new test words (see Table 2: main effects or interaction terms that do not include the factor of condition are not shown).

3.2.1. 400–700 ms
For both experiments the contrasts between the ERPs evoked by target hits and by correct judgements to new words (T vs. New: middle column) revealed three-way interactions between condition, AP and LR, reflecting the fact that the relatively greater positivity associated with target hits is smallest at right hemisphere sites, with these differences in the LR plane being most pronounced at posterior–parietal scalp locations. The same explanation holds for the three-way interaction term revealed by the contrast between the ERPs associated with non-target hits and new words in Experiment 1. The same contrast in Experiment 2 revealed a main effect of condition only, reflecting the fact that the ERPs elicited by non-targets are more positive-going than those elicited by new words.

The contrasts between the ERPs evoked by old words (T vs. NT) revealed main effects of condition, reflecting the fact that the mean amplitudes for target hits are more positive than those for non-target hits. In Experiment 2 only, the main effect was moderated by an interaction between condition, AP and LR, reflecting the fact that the differences between these classes of ERPs are small at right hemisphere locations, while at midline and left-hemisphere sites the greater positivity associated with target hits is more pronounced, primarily at central and parietal electrodes.

3.2.2. 700–1300 ms
Reliable effects involving condition were restricted to the contrasts involving new words, comprising interactions between condition and the AP and LR factors. In Experiment 1, these interaction terms reflect primarily the relatively greater positivity for correct judgements to new words, which is restricted to midline and right-hemisphere locations and is most pronounced at central scalp sites. In Experiment 2, these interactions reflect the relatively greater positivity for old compared to new words, which is right-lateralised and has a frontal maximum. A contributing factor common to both experiments is the relatively focal greater negativity for old than for new words at the Pz electrode.

3.2.3. Between-experiment analyses
These comprised direct contrasts of the ERP old/new effects from the two experiments, and were completed on mean amplitudes computed from subtraction waveforms obtained by subtracting the ERPs evoked by correct responses to new words from those evoked by target and non-target hits. Separate analyses were completed for targets and non-targets, each including factors of experiment, AP and LR, and using the same epochs and electrodes described above.

Reliable effects involving experiment were obtained for the 700–1300 ms epoch only, comprising interactions between experiment and the LR dimension (targets: $F(1.7,56.3) = 6.64, P < 0.01$; non-targets: $F(2.0,67.9) = 6.12, P < 0.01$). Fig. 3 shows that the principal disparities

![Fig. 3. Mean amplitudes (μV) of the ERP old/new effects in experiments 1 and 2 for non-targets (left-hand side) and targets over the 700–1300 ms time window. The mean amplitudes are collapsed across the anterior/posterior dimension. For each graph, L, left-hemisphere locations; M, midline; R, right hemisphere.](image-url)
between the ERP old/new effects are at midline and right hemisphere locations. The effects in Experiment 2 comprise a relatively greater positivity for old than for new words, which is evident primarily at right hemisphere sites. In Experiment 1 the effects comprise a relatively greater negativity for old compared to new words, which is evident at midline as well as at right hemisphere sites.

A final analysis was computed on data rescaled according to the max–min method in order to avoid confounding differences in magnitude with differences in topography [22]. This was computed jointly on the subtraction scores for targets and non-targets, including data from all 25 electrodes from which ERPs were acquired. The analysis (factors of experiment, condition and site), revealed an interaction between experiment and site ($F(3.8,127.9) = 2.81, P < 0.05$). This outcome confirms that the scalp distributions of the ERP old/new effects across experiments were reliably different in the 700–1300 ms time window, as Fig. 4 illustrates.

4. Discussion

Varying the time available to make memory judgements in exclusion tasks resulted in no overall changes in response accuracy, a decrease in RTs when an explicit response deadline was imposed, and qualitative changes in the ERP old/new effects. Changes in memory accuracy as a result of different response deadlines have been reported in a number of previous studies [44]. Some of these have involved manipulating response deadlines in recognition memory tasks with a view to making inferences about the nature and number of processes that support recognition (e.g. [12]). In related studies, the principal finding is that recognition memory judgements can be made at shorter deadlines than that possible with other task requirements were held constant.

When no explicit upper limit was imposed on the time to respond (Experiment 2), the ERP old/new effects were qualitatively similar to those in the majority of previous studies in which participants were asked to retrieve contextual information [6,27]. The 2.5 s upper limit in Experiment 1 had little influence on the ERP old/new effects prior to 700 ms post-stimulus, but resulted in effects from 700 ms onwards that differed in scalp distribution and polarity from those in Experiment 2. The implications of these qualitative differences between experiments will be discussed after first addressing the similarities between the ERP old/new effects at parietal locations in the 400–700 ms time window.

In both experiments, the parietal ERP old/new effects for target hits showed the characteristic left-greater-than-right asymmetry that has been reported in a number of previous studies [9]. For non-target hits, Figs. 1 and 2 illustrate that the asymmetry is present in both experiments, although it is more pronounced in Experiment 1. In keeping with this observation, statistical evidence for the asymmetry was obtained in Experiment 1 only. The null result may have come about because the parietal non-target old/new effect and asymmetry is relatively small, or because there is an important difference in the retrieval processes that were engaged in the two experiments. The latter possibility would have received strong support had the between-experiment analyses of the non-target ERP old/new effects revealed one or more reliable effects involving experiment. No such effects were obtained, and it is also notable that left-greater-than-right asymmetries for non-target old/new effects were evident in the data of Wilding and Rugg [41], who used speaker voice as the contextual information for the target/non-target discrimination and also had the same response demands as those in Experiment 2. In combination, therefore, these observations suggest that the absence of a
reliable asymmetry in Experiment 2 is a consequence of the size of the effect, although the alternative account discussed above cannot be ruled out.

An additional point of note concerning the parietal old/new effects in experiments 1 and 2 is that these were reliable for non-targets, as they were in the studies of Cycowicz et al. [3,4], and in the previous study of Wilding and Rugg [41]. Reliable non-target effects at these locations have also been reported recently by Van Petten et al. [36]. The nature of their task, however (associative recognition where recombined pairs were non-targets), means that their data do not speak to the points made below, as the following arguments illustrate.

The reason why reliable non-target parietal ERP old/new effects are noteworthy is because of a recent report by Herron and Rugg [11], who recorded ERPs during the test phases of two exclusion tasks. In both, the contextual information associated with non-targets at study was identical, but the contextual information associated with targets differed. Non-target accuracy was equivalent in the two experiments. A non-target left-parietal ERP old/new effect, however, was evident in only one of the two experiments.

The link between the left-parietal ERP old/new effect and recollection is well established (for reviews, see [1,9]), and in light of this, the findings of Herron and Rugg [11] suggest that some aspect of the target task influenced the likelihood that non-targets would be recollected. Crucially, the absence of the left-parietal ERP old/new effect for non-targets occurred in the experiment in which target accuracy was high. On the basis of this pattern of findings, Herron and Rugg [11] suggested that when memory for targets is relatively high, a strategy that will result in good task performance is to attempt to recollect information about targets only, and to use the presence or absence of such information to make the target/non-target discrimination. Thus the absence of the non-target parietal old/new effect came about because recollection of non-target information did not occur. Herron and Rugg suggested that the presence of the parietal effect for non-targets when target accuracy was lower reflected the fact that under these conditions a better strategy (in terms of maximising performance accuracy) is to attempt to recollect information about non-targets as well as targets.

An assumption key to this account is that participants can exert control over what information is recollected, and that the left-parietal old/new effect is sensitive to this. The data presented here, however, in combination with the previous findings of Cycowicz et al. [3,4], present a challenge to this account. The reason for this is that in each of these cases there was a reliable left-parietal ERP old/new effect for non-targets, despite the fact that target accuracy in all cases was markedly similar to that reported by Herron and Rugg [11] in the experiment where there was no non-target parietal old/new effect. One possibility is that the reliable non-target effects in these studies reflect the partial adoption of the strategy proposed by Herron and Rugg, which could presumably come about if only a proportion of participants adopted the strategy, or if some or all participants adopted the strategy sporadically during the task.

An alternative possibility is that the presence or absence of left-parietal ERP old/new effects for non-targets is influenced not only by the memorability of targets, but also by the correspondence between the kinds of contextual information associated with targets and with non-targets. According to this view, the similarity between target and non-target contextual information moderates the degree to which it is possible to recollect information associated with targets only, because when similarity is high at best partial control over recollection of non-target information is possible. The central notion here, then, is that recollection of non-target information will occur on some trials, or on the majority of trials but to a lesser degree, when target and non-target information is highly similar. Thus, according to this account, the absence of a parietal old/new effect for non-targets in the study due to Herron and Rugg [11] came about because the contextual information associated with targets and non-targets was sufficiently distinct to enable retrieval and/or subsequent processing of target information only. Meanwhile, in this study, the studies of Cycowicz et al. [3,4], and the study due to Wilding and Rugg [41], the similarities between target and non-target information were such that the same degree of selectivity could not be accomplished, hence the reliable parietal old/new effects in those studies.

Resolution of these questions concerning the functional characteristics of the left-parietal ERP old/new effects is important, because common to both of the foregoing accounts is the premise that the effect can be modulated according to retrieval demands. To the extent that the parietal effect indexes recollection, then these findings suggest that ERPs can provide a means of assessing the conditions under which control of recollection can be implemented, and ultimately insights into the mechanisms that facilitate such control [11].

Whatever the correct account for the data discussed above, the findings reported here are consistent with the view that the left-parietal ERP old/new effect is relatively immune to changes in the time available to make responses during episodic retrieval tasks, although it remains a possibility that this immunity does not extend to markedly shorter response intervals than those employed here. As mentioned previously, however, other ERP old/new effects were influenced by the response-deadline manipulation. From 700 ms post-stimulus, the ERP old/new effects obtained in the two experiments differed qualitatively.

The motivation for studying the influence of differing response-time demands on ERP old/new effects was consideration of the effects reported by Cycowicz et al. [3,4], and by Dywan et al. [8]. The scalp distributions of ERP old/new effects in those studies were dissimilar from those in a number of previous studies. In these three studies, moreover, the time in which a response was required was shorter...
than in the majority of previous ERP studies of episodic retrieval. In order to determine whether the divergences across studies were a general consequence of the imposition of response–time demands during episodic retrieval, a response-deadline was employed in Experiment 1 in a task requiring retrieval of source information (speaker voice) that was distinct from that in the studies of Dywan et al. and Cycowicz et al.

The critical data is the pattern of ERP old/new effects from 700 ms onwards, and in Experiment 1 the ERPs evoked by old words attracting correct judgements were relatively more negative-going than those evoked by correct judgements to new test words. This relative negativity was right-lateralised, and most pronounced at central scalp locations. In the previous studies, by contrast, the distribution was more diffuse, bilateral, and had a parietal maximum [3,4,8].

These divergences across the studies in which relatively short response deadlines were imposed suggest that the centro-parietal old/new effects in the studies of Cycowicz et al. and Dywan et al. [3,4,8] are not solely a consequence of the differential engagement of retrieval processes due to response-time demands. If this had been the case, then equivalent ERP old/new effects should have been observed in Experiment 1. The findings here provide some support, therefore, for Cycowicz et al.’s proposal [4] that the old/new effects in their studies index retrieval operations involved in the search for or retrieval of visual information, since similar effects are absent when comparable response demands obtain but the retrieval task involves retrieval of auditory source information. As noted in the Introduction, however, the surface correspondence between the findings of Cycowicz et al. [3,4] and those of Dywan et al. [8] challenges a content-specific account, since the tasks in the two studies required retrieval of distinct kinds of contextual information. This correspondence is at least consistent with the view that the parieto-central negativities in the two studies have a common functional correlate (for recent work that may shed light on this issue, see [16]).

In addition to diverging from findings in previous studies with short response deadlines, the ERP old/new effects in Experiment 1 were qualitatively distinct from those in Experiment 2, which also required retrieval of auditory source information, but had no explicit upper limit for responses. The findings in Experiment 2 correspond with those reported by Wilding and Rugg [41], who used an essentially identical design. Right-lateralised ERP old/new effects with similar time-courses have been reported in a number of previous studies (for recent reviews see [9,42]), but the functional significance of this modulation is unresolved. Three not entirely exclusive accounts are that the effect indexes: (1) processes that operate on the products of successful retrieval (e.g. [36,39])\(^3\), (2) retrieval monitoring operations that are engaged in modulating task performance and operate on the products of retrieval attempts (e.g. [29]), (3) search operations that are engaged in pursuit of task relevant information (e.g. [31]).

The findings from Experiment 2 provide no new information that might distinguish between these possibilities. Given that this is the first ERP paper to report the influence of modest response–time demands on retrieval processing, moreover, there is little prior work that speaks to the question of the nature of the processes that are indexed by the qualitatively different ERP old/new effects post 700 ms in Experiment 1, and their relationship with those engaged in Experiment 2. It seems reasonable to assume, however, that any of the foregoing possibilities discussed in respect of right-frontal ERP old/new effects can also apply to the effects obtained in Experiment 1.

As regards the relationship between the old/new effects post 700 ms in the two experiments, the qualitatively different effects may reflect the absence of one or more post-retrieval monitoring operations in Experiment 1 because the response–time limit was imposed. According to this account, therefore, successful completion of the task in Experiment 1 was accomplished with only some of the processes that were engaged in Experiment 2. Given that response accuracy was equivalent in the two experiments, it follows that whatever additional monitoring processes were engaged without time pressure in Experiment 2 did not aid response accuracy, but might have influenced variables such as response confidence that were not assessed here.

An alternative perspective is that the different response–time demands prompted the engagement of monitoring processes that were unique to each experiment. For this account, the equivalent levels of response accuracy across experiments can be accomplished by assuming the following. First, that there are two sets of monitoring operations which are equally influential for response accuracy. Second, that variations in time pressure dictate which will be engaged, perhaps because those in Experiment 1 are more resource intensive but take less time to complete than those in Experiment 2.

Irrespective of whether either of these general accounts turn out to be correct, two aspects of the data reported here provide support for the source-monitoring framework of Johnson et al. (SMF, see Section 1 and [19]). As noted in the Introduction, the SMF allows for retrieval monitoring and decision processes to be engaged flexibly according to task demands. The first aspect that supports this framework is the qualitatively different ERP old/new effects that were obtained in experiments 1 and 2, where the only task demands to differ were the response–time requirements. The second aspect is the morphologically distinct ERP old/new effects that were obtained in Experiment 1 in comparison to other studies in which short response–time intervals have been employed [3,4,8]. A beguiling conclusion that follows from these disparities across studies is that under some circumstances ERPs index content-specific retrieval

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\(^3\) This account may apply to a frontally distributed modulation with a bilateral rather than a right-lateralised distribution: see also [31,35].
processes. Whether this is in fact the case will ultimately be determined in subsequent studies in which all task requirements other than retrieval content are held constant.

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