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Electrophysiological indices of strategic episodic retrieval processing

M.A. Dzulkifli, E.L. Wilding*

School of Psychology, Cardiff University, Park Place, Cardiff, CF10 3AT, Wales, UK

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Abstract

Event-related potentials (ERPs) were acquired during test phases of a recognition memory exclusion task, in order to contribute to current understanding of the processes responsible for the ways in which memory retrieval can be controlled strategically. Participants were asked to endorse old words from one study task (targets) and to reject new test words as well as those from a second study task (non-targets). The study task designated as the target category varied across test phases. The left-parietal ERP old/new effect – the electrophysiological signature of recollection – was reliable for targets only in all test phases, consistent with the view that participants control recollection strategically in service of task demands. The contrast between the ERPs evoked by new test words separated according to target designation revealed reliable differences at midline, anterior and right-hemisphere locations. These differences likely reflect processes that form part of a retrieval attempt and are interpreted here as indices of processes that are important for the strategic regulation of episodic retrieval.

Keywords: Episodic memory; Recollection; Event-related potentials; Retrieval orientation; Retrieval processing

1. Introduction

In a recent review, Rugg and Wilding (2000) discussed the concept of retrieval orientation, a task set that is entered when there is a need for episodic retrieval (see also Wilding, 1999; Wilding & Sharpe, 2003). Retrieval orientation is related to an older concept – retrieval mode (Lepage, Ghaffar, Nyberg, & Tulving, 2000; Tulving, 1983; Wheeler, Stuss, & Tulving, 1997). Common to both is the assumption that they ensure stimuli will be treated as episodic retrieval cues. That is, they determine the processes set in train when a potential retrieval cue is encountered (for related concepts, see Johnson, 1983, 1992; Johnson, Hashtroudi, & Lindsay, 1993). The distinction between the two is that while mode is considered to be invariant across different episodic retrieval tasks, orientation varies according to specific task demands (Rugg & Wilding, 2000).

The majority of research into retrieval orientation has been in ERP studies of episodic retrieval (also see Dobbins, Rice, Wagner, & Schacter, 2003; Ranganath, Johnson, & D'Esposito, 2000), where the most common approach to identifying correlates of orientation involves contrasting ERPs evoked by new (unstudied) test items across tasks having different retrieval demands. Restricting contrasts to new items minimises the possibility of contamination by indices of successful episodic retrieval (Donaldson, Wilding, & Allan, 2003), and the results in several studies show that the ERPs evoked by new items do vary according to retrieval demands, and that these differences are not simply a reflection of reaction time or difficulty changes across tasks (Ranganath & Paller, 2000; Robb & Rugg, 2002; Wilding, 1999).

The reason, presumably, why it is possible to adopt specific retrieval orientations is because they confer benefits on subsequent memory retrieval (Herron & Wilding, 2004; Johnson, 1992; Wilding & Nobre, 2001), and in keeping with this view it has been suggested recently that ERP indices of orientation index strategic retrieval processes that enable selective access to only some kinds of information held in memory (Herron & Rugg, 2003a). This study was designed in order to assess this account, by linking ERP indices of retrieval orientation to evidence from other aspects of test-recorded ERPs that can indicate when episodic retrieval has been restricted to only some kinds of information that are available.

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* Corresponding author. Tel.: +44 2920 875048; fax: +44 2920 874858. *E-mail address:* wildinge@cardiff.ac.uk (E.L. Wilding).

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In order to accomplish this, ERPs were acquired during the retrieval phases of exclusion tasks (Jacoby, 1991), in which an 'old' response is to be made to one class of old items (targets), and a 'new' response is to be made to the other class (non-targets) as well as to new items. In this experiment, participants initially completed two interleaved encoding tasks, both slight variants of those employed by Johnson, Kounios, and Nolde (1996). In the Function task, participants thought of suitable functions for the objects denoted by visually presented words. In the Drawing task, participants rated how easy the objects denoted by each word would be to draw. In separate retrieval phases, words from either the function or the drawing task were designated as targets.

This design permits a contrast between the ERPs evoked by new test words separated according to target designation. In keeping with the logic outlined above, differences between these classes of ERPs would suggest that participants adopted different orientations according to retrieval demands – whether targets were words encoded in the function or the drawing condition. In addition, this design permits an analysis of ERP correlates of successful retrieval (ERP old/new effects) that are obtained by contrasting the ERPs associated with correct judgments to old and new test words.

Of particular interest here is the left-parietal ERP old/new effect, which is largest over left-parietal scalp from 500 to 800 ms post-stimulus and comprises a relatively greater positivity for correct judgments to old compared to new items. The weight of evidence suggests that the effect is an electrophysiological index of recollection (Friedman & Johnson, 2000; Rugg & Allan, 2000; Wilding & Sharpe, 2003), and the reason why this effect is important here is because in some exclusion tasks (Herron & Rugg, 2003a, 2003b) as well as close variants (Dywan, Segalowitz, & Arsenault, 2002; Dywan, Segalowitz, & Webster, 1998; Dywan, Segalowitz, Webster, Hendry, & Harding, 2001) correct target judgments have elicited reliable left-parietal old/new effects, while correct non-target judgments have not. These findings have led to the proposal that in these tasks recollection of information associated with non-targets occurred markedly less often than recollection of information associated with targets (Herron & Rugg, 2003a, 2003b).

This proposal is important, because one feature of the exclusion task is that it is not possible on the basis of the behavioural data alone to determine whether recollection of information associated with targets as well as with non-targets occurred. For example, if the likelihood of recollecting target-related information is high, then one strategy that will enable good task performance is to attempt to recollect information about targets only, and to make a target response *only* to items on which successful recollection of target material occurred. The effectiveness of this strategy diminishes, however, as the likelihood of recollecting information associated with targets decreases (Herron & Rugg, 2003b). According to this account, therefore, in some circumstances recollection of non-targets is not necessary for accurate performance on the exclusion task.

The findings in the aforementioned ERP studies are consistent with the view that a strategy of prioritising recollection of information about targets was adopted when the likelihood of recollecting target information was high (Herron & Rugg, 2003a, 2003b), and support for this account comes also from participant reports of the strategies they adopted while completing exclusion tasks (Herron & Rugg, 2003b). Of particular relevance here is one study by Herron and Rugg (2003a), in which the encoding phase comprised presentation of words and pictures. Test stimuli were words, and the old words were either re-presentations of study words, or of words corresponding to the objects shown in the pictures. In separate retrieval phases, targets were designated as old words encountered either as words or pictures at encoding. This design enabled contrasts between the ERPs associated with correct responses to new items separated according to target designation (word/picture), as well as between the left-parietal ERP old/new effects associated with targets and non-targets, also separated according to designation.

The ERPs evoked by new words in the word-target condition were more positive-going than those evoked in the picture-target condition. These differences onset approximately 300 ms, were largest at central midline sites, and lasted for 500–600 ms (also see Morcom & Rugg, 2004; Robb & Rugg, 2002). In addition, there were reliable parietal old/new effects for targets in both target designations, but reliable parietal effects for non-targets only when pictures were designated as targets. In keeping with the reasoning given above, this suggests that, at least in the word-target condition,[1] participants adopted a strategy of attempting to recollect information about targets only, and on this basis Herron and Rugg (2003a) proposed that differences between the ERPs evoked by new items indexed processes that permitted recollection to be restricted to certain kinds of studied information.

The experiment reported here has a design similar to that of Herron and Rugg (2003a), the principal departures being the use of encoding tasks requiring different cognitive operations, and the use of visually presented words at both encoding and retrieval. In this experiment, attenuated left-parietal ERP old/new effects for non-targets in comparison to targets would demonstrate that the findings of Herron and Rugg (2003a) generalise to conditions under which modality at encoding and retrieval is held constant, and where encoding operations differ only in terms of the processing to which study words were subjected. Reliable indices of retrieval orientation, as revealed by differences between ERPs evoked by unstudied words and separated according to target designation, would also provide converging evidence for the view

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[1] Herron and Rugg discuss two possibilities that can explain the presence of non-target left-parietal ERP old/new effects in the picture-target condition. The question of the conditions under which it is or is not possible to constrain retrieval processing is important (also see Wilding & Sharpe, 2004), but for present purposes, the key issue is that the ERP data in several studies indicate there are at least some circumstances under which selective retrieval can be accomplished.

that one function of orientations is to influence the retrieval processes that targets and non-targets are associated with.

2. Method

2.1. Participants

Twenty-one right-handed participants (six males) gave informed consent and were paid £5 per hour. Data from three female participants were discarded due to experimenter error (1) and excessive EOG artefacts (2, see below). The average age of the remaining participants was 21 (range: 18–29).

2.2. Stimuli and design

Three hundred and sixty words from the Kucera and Francis (1967) corpus were presented in white letters on a black background on a computer monitor 1 m from participants (frequency 1–7/million, 3–10 letters in length). Maximum horizontal and vertical visual angles were 2.2° and 1.4°. One complete 360-word task list comprised two study-test cycles. The 360 words were split into six equal groups, with three groups in each cycle. Words appeared in only one cycle. The study phase of each cycle comprised two groups (120 words). An asterisk preceded one group of words, a plus sign the other, these cues signalling the task participants should complete for each word (see Section 2.3). Rotating the groups of words across study and test within each cycle created three task lists. Across lists all words appeared after an asterisk and a plus sign, and all were presented at study and test as well as at test only. The order of presentation of words at study and at test within cycles was determined randomly for each participant. Filler words were placed at the beginning of study and test phases. Three hundred and two stimuli were in each study-test cycle (120 study stimuli, 180 test stimuli + 2 fillers).

2.3. Procedure

Participants were fitted with an electrode cap prior to the experiment. In each study phase, participants completed one of two tasks on each word. In the function task, they were asked to say aloud a suitable function for the object denoted by the word. In the drawing task, they were asked to rate verbally the difficulty of drawing the object denoted by the word on a 5-point scale: 1 = 'very easy', 5 = 'very difficult'. For half of the participants, an asterisk before study words signalled a function judgment should be made, and a plus sign signalled a drawing judgment should be made. This correspondence was reversed for the other half. One of these cues initiated each study trial and remained on the screen for 1000 ms. The screen was then blanked (100 ms) before the study word was presented for 300 ms. After a 1500-ms gap, the message PLEASE SPEAK NOW appeared. Participants were asked to withhold their response until this message appeared. The message was removed when participants pressed a key. The next trial started 1000 ms later.

Each test trial started with a fixation asterisk (500 ms duration), which was removed from the screen 100 ms prior to presentation of a test word (300 ms duration). The screen was then blanked until the participant responded, and the next trial started 1200 ms after the response. Participants were asked to balance response speed and accuracy equally. For each test phase, participants responded with one hand to words from the function/drawing study task (targets), and with the other to words from the alternate task (non-targets), as well as to unstudied test words. Responses were made on a keypad with the left and right thumbs. The thumbs used for responses were balanced across participants, and participants were informed of target designation for each test phase only at the start of that phase. An equal number of participants completed the function/drawing target designation condition first. Participants were informed prior to the experiment that target designation would not necessarily differ across cycles. A short break was given after each phase.

2.4. ERP recording

Recording locations from the International 10–20 system (Jasper, 1958) comprised midline (Fz, Cz, Pz), left and right hemisphere sites (FP1/FP2, F7/F8, F5/F6, F3/F4, T7/T8, C5/C6, C3/C4, P7/P8, P5/P6, P3/P4, O1/O2) and the mastoid processes. EEG was acquired continuously (6 ms/point) over a frequency band of 0.03–40 Hz with Fz as reference. Vertical and horizontal EOG were recorded bipolarly from electrodes placed above and below the right eye, and on the outer canthi of the eyes. ERPs were re-referenced off-line to linked mastoids and this procedure permits the data from the reference site during acquisition (Fz) to be calculated. Data were epoched off-line (1536 ms (256-point) epochs, with a 102 ms pre-stimulus baseline, relative to which all mean amplitudes were computed). Trials containing large EOG artefact and those containing A/D saturation or baseline drift exceeding ±80 μV were rejected. Other EOG blink artefacts were corrected using a linear regression estimate (Semlitsch, Anderer, Schuster, & Presslich, 1986).

3. Results

3.1. Behavioural data

Table 1 shows reaction times (RTs) and probabilities of correct responses for targets, non-targets and new (unstudied) words, separated according to target designation. There were more target responses to targets than to non-targets and new words in each designation ($t(17) > 15.0$, $P < 0.001$ in each case). ANOVA with factors of designation (function/drawing) and condition (target/non-target/new) revealed a main effect of condition only ($F(1.4, 24.6) = 44.52$, $P < 0.001$: in this and in all

Table 1
Probabilities of correct responses (*P*(correct)) and reaction times (RTs) to targets, non-targets and new words in the function and drawing target designation conditions

Target		Word type		
		New	Target	Non-target
Function	*P*(correct)	0.99 (0.12)	0.83 (0.09)	0.89 (0.08)
	RT	1086 (377)	1357 (418)	1357 (450)
Drawing	*P*(correct)	0.98 (0.04)	0.81 (0.12)	0.90 (0.09)
	RT	1005 (166)	1209 (299)	1287 (305)

S.D. in parentheses.

other ANOVAs, the Geisser–Greenhouse correction for non-sphericity was employed where necessary (Winer, 1971), and corrected degrees of freedom are shown as appropriate). Post hoc analyses (Newman–Keuls) indicated that: (i) correct judgments to unstudied words were more likely than correct judgments to studied words and (ii) correct target judgments were less likely than correct non-target judgments. ANOVA of the RTs (factors as for response accuracy) revealed a main effect of condition only ($F(1, 17) = 46.61$, $P < 0.001$). Post hoc analyses (Newman–Keuls) revealed only that correct responses to new words were faster than correct responses to targets as well as non-targets.

3.2. ERP data

The ERPs evoked by new words attracting correct judgments are shown in Fig. 1 for the nine electrode sites (F5, Fz, F6, C5, Cz, C6, P5, Pz, P6) used in the initial ANOVAs of these ERPs, which included factors of target designation (function/drawing), the anterior/posterior (AP: frontal/central/posterior), and lateral (LR: left/midline/right) dimensions. In the absence of a priori hypotheses concerning the likely locations and the time-courses of differences between response categories, the analyses were conducted over successive 100 ms epochs from 300 to 1200 ms.

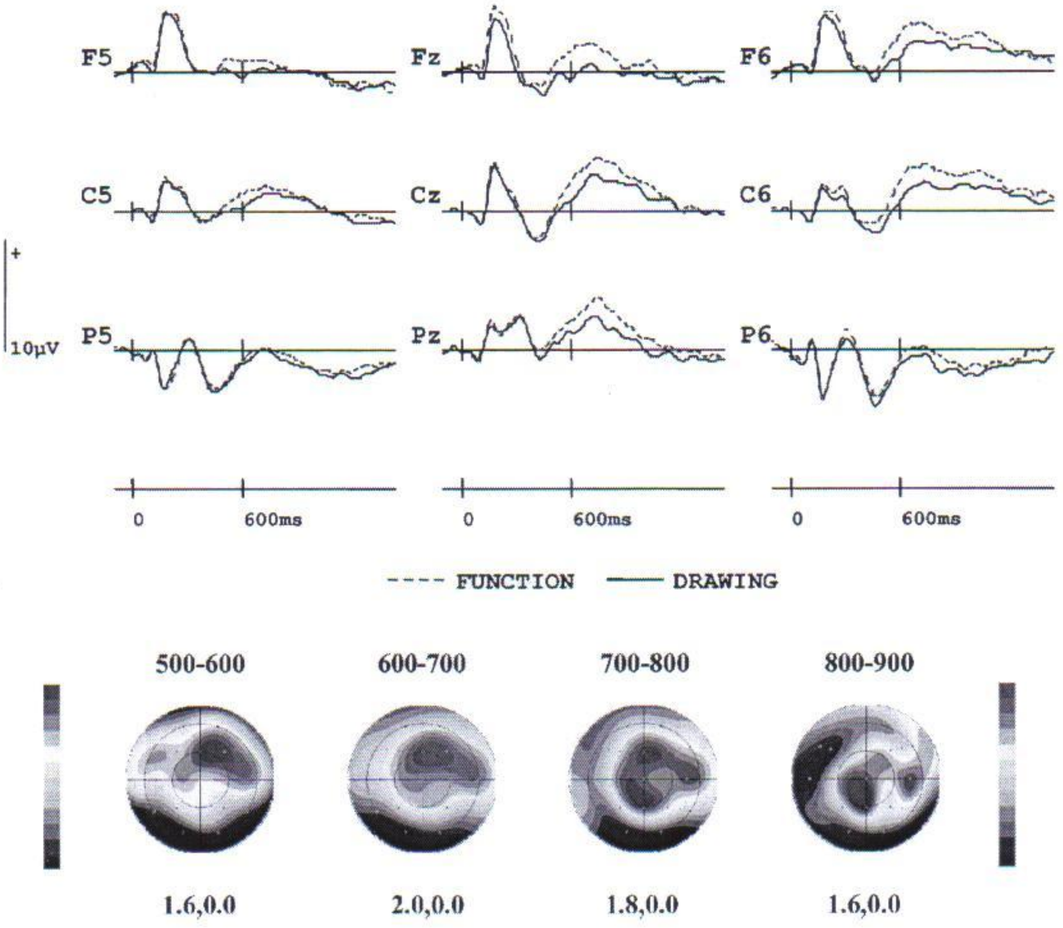

Fig. 1. Grand average ERPs evoked by new words in the two target designation conditions. The data are shown for nine locations at midline as well as left- and right-hemisphere sites over anterior (F5, Fz, F6), central (C5, Cz, C6) and posterior scalp (P5, Pz, P6). The figure also shows scalp distributions for the 100 ms time windows in which reliable differences between conditions were obtained (see Table 2). These were computed from the scores obtained by subtracting mean amplitudes from the ERPs evoked by new words in the drawing designation condition from those in the function condition. The paired values below each map denote the maxima and minima of the amplitude differences between conditions, and can be interpreted relative to the bars on the two sides of the figure. For example, for the 500–600 ms epoch, the top of the bar (white) denotes 1.6 µV while the bottom (black) denotes 0 µV.

Table 2
The outcomes of the direct contrasts between the ERPs evoked by new (unstudied) test words in the function and the drawing target designation conditions

Epoch	500–600	600–700	700–800	800–900	900–1000	1000–1100
TD ($F(1,17)$)	8.27^{**}	13.74^{***}	8.40^{***}	5.09^{**}		3.88^{*}
TD × LR ($F(2,34)$)			$4.13\ (0.93)^{**}$	$3.81\ (0.91)^{**}$	3.00^{*}	3.06^{*}

The outcomes are shown only for those time windows (500–1100 ms) and factors where reliable or marginal effects were obtained; these factors were target designation (TD) and the LR (left/midline/right) dimension; epsilon values are given in parentheses.

* $P<0.1$.

** $P<.05$.

*** $P<.01$.

Table 2 shows all the reliable and marginal effects involving target designation, which were evident from 500 to 1100 ms. The ERPs evoked by new words in the function task were reliably more positive-going than those evoked in the drawing task from 500 to 900 ms. The interactions between designation and LR – reliable from 700 to 900 ms – were followed up by directed separate analyses at midline as well as right- and left-hemisphere sites. These interactions reflect the fact that the ERPs from the function task are more positive-going than those from the drawing task at right-hemisphere and midline locations only (midline – 700–800: $F(1,17)=8.90$, $P<0.05$; 800–900: $F(1,17)=6.10$, $P<0.05$; right hem – 700–800: $F(1,17)=7.85$, $P<0.05$; 800–900: $F(1,17)=4.83$, $P<0.05$). Fig. 1 (bottom) shows the scalp distributions of the differences between the two classes of ERPs evoked by new items over the epochs where there were reliable effects of target designation.

Fig. 2 shows the ERP old/new effects from the two target designations. The initial analyses were run in order to determine the relationship between the left-parietal ERP old/new effects for targets and non-targets. These were restricted to data from P5 over the 500–800 ms epoch. This location and epoch corresponds to that over which parietal ERP old/new effects are typically largest (Wilding & Sharpe, 2003), and over which possible contamination with P300-related activity is limited (see Section 4, as well as Herron, Quayle, & Rugg, 2003).

The initial analysis (factors of target designation and response category) revealed a main effect of response category only ($F(1.5,25.1)=8.89$, $P<0.01$). Follow-up analyses collapsed across target designation revealed that the ERPs evoked by targets were more positive-going than those evoked by non-targets ($F(1,17)=12.64$, $P<0.01$) and new words ($F(1,17)=17.71$, $P<0.01$). The ERPs evoked by new words and by non-targets were not reliably different, and nor were the ERPs evoked by new words when they were analysed at P5 separated according to target designation.

The outcomes of the foregoing analyses speak to the principal issues that this study was designed to address. Below, we report the outcomes of global analyses of the ERP old/new effects obtained in this study. They are of interest because they permit inspection of the correspondence between these data and those in similar ERP studies. The effects were analysed using data from the 3 × 3 electrode array described above over 4 epochs (300–500, 500–800, 800–1100 and 1100–1400 ms) selected on the basis of previous findings (Rugg & Allan, 2000). ANOVAs included factors of designation, response category, LR and AP. Follow-up ANOVAs were employed to decompose interactions involving response category, and subsequent post hoc analyses (Newman–Keuls) were employed to determine the reasons for interactions involving scalp location (the AP and/or LR factors).

3.3. 300–500 ms

The analysis revealed a main effect of response category ($F(1.9,31.7)=6.75$, $P<0.01$) and a category × LR interaction ($F(2.8,47.7)=4.15$, $P<0.025$). Follow-up analyses (all possible paired contrasts) were collapsed across target designation. The target versus non-target contrast revealed no effects involving category, while the analyses involving new items revealed main effects of category (targets: $F(1,17)=9.78$, $P<0.01$; non-targets: $F(1,17)=7.64$, $P<0.025$), as well as category × LR interactions (targets: $F(1.9,31.8)=5.42$, $P<0.025$; non-targets: $F(1.8,31.2)=3.93$, $P<0.05$). Post hoc analyses revealed that for both classes of old word the differences between categories were reliable at midline locations only.

3.4. 500–800 ms

The initial analysis revealed designation × category × AP ($F(2.8,48.0)=2.53$, $P<0.025$) and category × AP × LR ($F(2.6,42.8)=5.22$, $P<0.01$) interactions. Paired contrasts for the function target designation revealed a category × AP × LR interaction for targets only ($F(1.9,31.5)=5.44$, $P<0.025$). For non-targets, this interaction approached significance ($F(2.3,39.4)=2.91$, $P<0.06$), as did the category × LR interaction ($F(1.8,30.1)=3.42$, $P=0.05$). The post hoc analyses revealed that these interactions reflect the focal positivity for new items in comparison to targets at right-hemisphere central locations, and the relatively greater positivity for targets than for new words at left-parietal locations.

For the drawing target designation, paired contrasts involving new words revealed category × AP × LR interactions (targets: $F(2.1,35.0)=5.35$, $P<0.01$; non-targets: $F(2.2,37.1)=3.93$, $P<0.025$). The post hoc analyses revealed that the old/new effects were reliable for targets only at left posterior scalp locations. The target versus

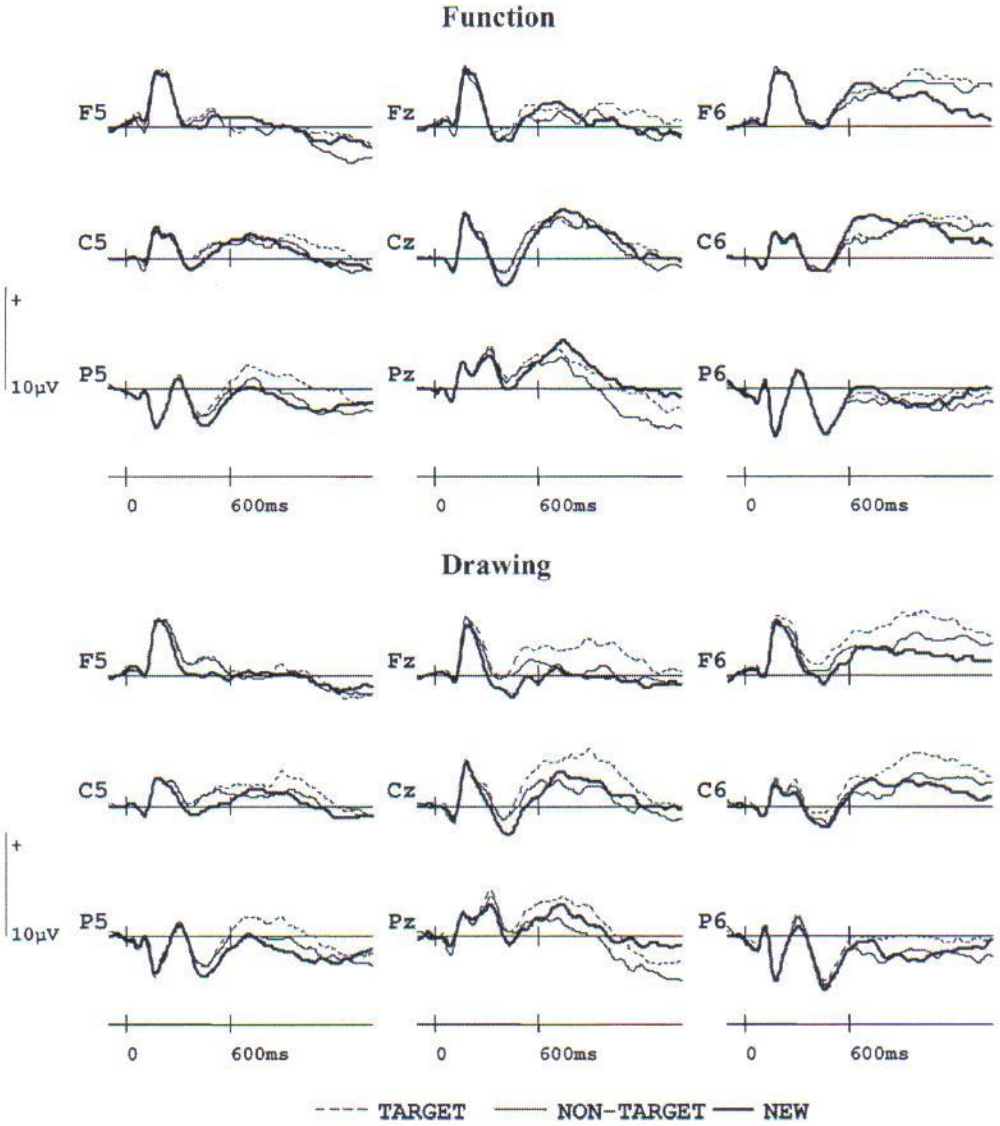

Fig. 2. Grand average ERPs evoked by correct judgments to targets, non-targets and new words in the function target (upper panel) and drawing target designation conditions. Electrode locations as in Fig. 1.

non-target contrast revealed a main effect of category ($F(1, 17) = 15.46$, $P < 0.01$) and a category × LR interaction ($F(1.8, 29.8) = 5.38$, $P < 0.025$). The post hoc analyses revealed that targets were more positive at midline and left- but not at right-hemisphere locations.

3.5. 800–1100 ms

The initial analysis revealed designation × category × LR ($F(3.4, 58.0) = 3.59$, $P < 0.025$) and category × AP × LR ($F(2.9, 49.6) = 8.47$, $P < 0.001$) interactions. Reliable effects involving category for the function target designation were restricted to interactions between category, AP and LR for the contrasts involving new words (targets: $F(1.7, 28.7) = 7.56$, $P < 0.01$; non-targets: $F(2.1, 36.2) = 6.35$, $P < 0.01$). The reasons for these interactions were not clarified by the post hoc analyses, but they likely reflect the fact that the right-greater-than-left asymmetry of the old/new effects anteriorly is not mirrored at central and posterior locations, with both classes of old words showing a focal relative negativity compared to new words at midline posterior scalp locations.

For the drawing target designation, both contrasts involving new words revealed category × AP × LR interactions (targets: $F(2.1, 35.3) = 10.09$, $P < 0.01$: non-targets: $F(2.7, 45.9) = 5.38$, $P < 0.01$). The target versus new contrast revealed a main effect of category ($F(1, 17) = 13.46$, $P < 0.01$). These effects reflect primarily the fact that the right-greater-than-left asymmetry for the positive-going ERP old/new effects at anterior locations is reversed at posterior locations, although this was not confirmed by the post hoc analyses. The main effect of category ($F(1,17)=21.53$, $P<0.001$) and the interaction with LR ($F(1.7,28.2)=8.24$, $P<0.001$) for the target/non-target contrast arise because the greater relative positivity for targets is reliable at midline and right-hemisphere scalp locations only.

3.6. 1100–1400 ms

The initial analysis revealed no reliable effects involving target designation, but a main effect of category ($F(1.7,28.8)=4.53$, $P<0.025$) as well as interactions with this factor and AP ($F(1.8,30.7)=3.59$, $P<0.05$), LR ($F(3.4,57.2)=7.74$, $P<0.001$), and AP with LR ($F(4.3,73.6)=8.92$, $P<0.001$). Follow-up analyses were collapsed across target designation. Targets are more positive-going than non-targets ($F(1,17)=13.69$, $P<0.01$). The contrasts involving new words revealed interactions for category × LR (targets: $F(1.9,32.3)=8.39$, $P<0.01$; non-targets: $F(1.9,32.8)=10.64$, $P<0.001$), category × AP (targets: $F(1.3,21.8)=4.20$, $P<0.05$; non-targets: $F(1.2,20.0)=4.17$, $P<0.05$), as well as category × AP × LR (targets: $F(2.9,48.9)=15.55$, $P<0.001$; non-targets: $F(2.3,39.4)=10.49$, $P<0.001$). The target versus new contrast also revealed a main effect of category ($F(1,17)=4.66$, $P<0.05$). The post hoc analyses decomposing the three-way interactions revealed no reliable effects, and the interactions likely reflect the fact that the relatively greater positivity for the ERPs evoked by old words at anterior locations is greater over the right than the left hemisphere, while at more posterior locations there is less hemisphere asymmetry, and a relatively greater negativity for old words which is largest at the midline.

3.7. Analyses of scalp distribution

Fig. 3 suggests that the scalp distributions of the target and the non-target ERP old/new effects change with time and target designation. The foregoing analyses revealed interactions involving designation and location from 500 to 1100 ms, which suggests qualitative differences between the ERP old/new effects, in turn suggesting that not entirely the same neural generators were engaged according to designation. Since the presence of qualitative differences between conditions cannot be inferred unambiguously from data that has not been rescaled, mean amplitudes from the 500 to 800 and 800 to 1100 ms epochs were analysed separately after rescaling using the max–min method described by McCarthy and Wood (1985). This was computed on the subtraction scores across all scalp locations obtained by subtracting mean amplitudes of the ERPs evoked by new words from those evoked by targets and non-targets, separated according to designation. The analyses were restricted to the same

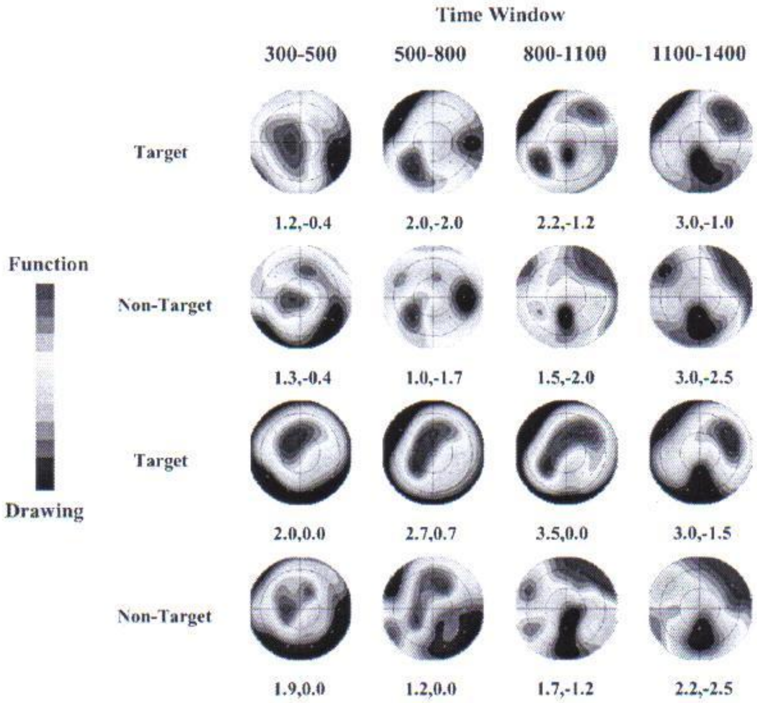

Fig. 3. Topographic maps depicting the scalp distributions of the old/new effects for targets and for non-targets, separated according to target designation (function/drawing) and epoch (300–500, 500–800, 800–1100, 1100–1400 ms). The maps were computed on difference scores obtained by subtracting the mean amplitudes for correct rejections from those for targets and non-targets in the two target designation conditions. For explanation of the paired values below each map, see legend for Fig. 1.

3×3 array of electrode sites described above. They revealed no effects of target/non-target status and effects involving designation for the 500–800 ms epoch only (designation × AP: $F(1.9, 31.8) = 5.26$, $P < 0.025$), reflecting the fact that while the distributions of the ERP old/new effects over this epoch are similar at posterior locations, ERP old/new effects are also prominent at anterior locations in the drawing target designation condition.

4. Discussion

The analysis of the ERPs revealed several modulations that varied according to task, old/new status and target/non-target status. In keeping with the issues outlined in Section 1, of particular interest here are differences between the ERPs evoked by new words, and differences between the left-parietal ERP old/new effects evoked by targets and by non-targets. We return to these aspects of the data after commenting on three other findings.

First, in the 300–500 ms time window there was no statistical evidence that the ERP old/new effects varied according to target designation or target/non-target status, in contrast to the findings in subsequent epochs. The functional significance of ERP old/new effects in this time window is a matter of current debate (cf. Curran, 2000; Mecklinger, 2000; Tsivilis, Otten, & Rugg, 2001; Yovel & Paller, 2004), and while the data reported here cannot distinguish between conflicting accounts, the immunity of the effects to designation and status emphasises that the memory-related processes indexed in this epoch are functionally dissociable from those indexed in later epochs.

Second, from 800 ms post-stimulus onwards, the ERP old/new effects that were obtained in the two tasks show the right-anterior distribution that has been reported in previous ERP studies in which source judgments have been required (for commentary, see Van Petten, Senkfor, & Newberg, 2000). Also evident at Pz in Figs. 2 and 3 is the late posterior negativity that may reflect a combination of response-locked and stimulus-locked processes (Cycowicz, Friedman, & Duff, 2003; Cycowicz, Friedman, & Snodgrass, 2001; Johannsen & Mecklinger, 2003). In the case of both these effects, the current data contribute nothing new to the question of their functional significance.

Third, there are qualitative differences between the scalp distributions of the old/new effects in the target designation conditions from 500 to 800 ms. While the ERP old/new effects in both designations share positive-going ERP old/new effects at left-posterior electrode locations, there is a positive-going ERP old/new effect in the drawing designation at fronto-central locations, and a negative-going effect in the function designation at right–central locations. These differences, as Figs. 1 and 3 show, are carried primarily by the differences between the ERPs evoked by new test words, where those from the function target designation condition are more positive-going over the scalp regions that also differentiate the ERP old/new effects. In previous studies, it has been assumed that qualitative differences between ERP old/new effects can provide evidence consistent with the view that retrieval of different contents depends upon distinct brain regions (Allan, Robb, & Rugg, 2000; Donaldson et al., 2003), in keeping with the view that memories reside at least partially in the brain regions engaged during encoding, and that remembering involves recapitulation of activity in those regions (Damasio, 1989a, 1989b; Mesulam, 1990, 1998; Squire & Alvarez, 1995). The findings reported here can be regarded as a cautionary note in this context, in that when old/new effects are employed in this way, evidence consistent with a recapitulation account can stem from the engagement of task-specific retrieval processes modulating what is retrieved rather than reflecting retrieval per se.

We turn now to the relationship between the ERPs evoked by new words, the left-parietal ERP old/new effects and the behavioural data. The ERPs evoked by new words in the function target designation were more positive than those from the drawing target designation from 500 to 900 ms post-stimulus. These differences were larger over the right hemisphere from 700 to 900 ms. Johnson et al. (1996) reported somewhat different divergences between ERPs evoked by new words in a study with very similar encoding tasks. The exact nature of the disparities across the two studies is not determined readily, however, as the ERPs evoked by new words in the critical conditions were not shown in the study of Johnson et al. since they were not the principal focus in the paper. Of greater importance, the two experiments had different response requirements at test, and in the study of Johnson et al. for each participant half of the stimuli at encoding were words, and the other half were pictures. One or more of these differences between designs may have resulted in different retrieval demands in the two experiments, thus explaining the disparities between the ERP data.

For the present data, the differences between the ERPs evoked by unstudied test words were obtained despite equivalent levels of memory performance and no reliable differences between RTs across target designation. These findings suggest that the differences between these ERPs cannot be explained solely in terms of changes in task difficulty, an interpretation supported by the findings of Robb and Rugg (2002) who demonstrated that electrophysiological indices of retrieval effort and retrieval orientation can be temporally distinct (also see Dzulkifli, Sharpe, & Wilding, 2004).

The findings of Robb and Rugg (2002), alongside those of Herron and Rugg (2003a), are important here because the ways in which the ERPs evoked by new items diverge in their work is similar in time course but not in scalp distribution to the data that are reported here. These disparities across studies in which different encoding and retrieval tasks have been employed (see also Ranganath & Paller, 1999, 2000; Rugg, Allan, & Birch, 2000; Wilding, 1999) are consistent with the view that task-specific retrieval processing was engaged in the function and the drawing target designation conditions.

The left-parietal ERP old/new effects and the accuracy data from the two target designations provide clues to a more precise functional characterisation of these indices of task-specific processing. The accuracy of correct target, non-target and new judgments was high and statistically equivalent across target designations, indicating that participants were able to recollect information about the encoding tasks in order to make the target/non-target distinction. Importantly, however, the behavioural data do not mandate that participants recollected information equally about targets as well as non-targets in order to do this, and the pattern of ERP old/new effects in this study is relevant to this consideration.

Reliable left-parietal ERP old/new effects were elicited by targets only, and given the link between this effect and recollection the absence of comparable effects for non-targets is striking, not least because the accuracy of target and non-target judgments was high. The data are therefore consistent with Herron and Rugg's (2003b) proposal that when target accuracy is high participants adopt a strategy of attempting to recollect information about targets only. The reason why this is a sound strategy is because as the likelihood of target recollection increases so does the diagnostic value of the success or failure of recollection of information about targets only as a basis for accurate task judgments (Herron & Rugg, 2003a, 2003b).

While these findings are consistent with this account, they do not, however, indicate unequivocally that no recollection of non-targets occurred. This is because the non-significant effects for non-targets may have come about simply because less episodic information about non-targets than targets was recovered, and/or because the proportion of trials on which recollection occurred was greater for targets than for non-targets. The conclusions drawn from this pattern of old/new effects, moreover, depend upon the precise functional significance of the left-parietal effect. Whether the effect is a comprehensive index of recollection cannot be determined, thus for this reason also, the data are equivocal with respect to the possibility that no information about non-targets was in fact recollected (for further comment, see Herron & Rugg, 2003a). The fact remains, nevertheless, that the marked attenuation of a modulation of the electrical record that is correlated with recollection suggests that a high degree of control over episodic retrieval was exerted, and it seems reasonable to conclude that at least some retrieval processes tied closely to recollection were engaged to a significantly greater extent for targets than for non-targets. As noted in Section 1, this conclusion is compatible with the subjective reports given by participants in previous studies, and while equivalent data are not available in the present study, the ERP data are broadly consistent with the view that participants prioritised recollection of target-relevant material.

On the basis of this interpretation of the pattern of ERP old/new effects, we propose that the differences between the ERPs evoked by new items in the two tasks reflect processes that are engaged in pursuit of recovery of target-relevant information only. This interpretation is supported by the findings for the ERP old/new effects, and also by the fact that in both target designation conditions the information potentially available for the target/non-target distinction was identical: all that differed was target designation. This interpretation is also broadly similar to that offered by Johnson et al. (1996) in their ERP study of source monitoring: they suggested that differences between ERPs evoked by classes of unstudied words reflected the different ways in which memory traces were probed for different kinds of information. An important difference, however, is that while we do not advocate a locus at which these operations act, in the paper due to Johnson et al., the emphasis is placed upon evaluating the information that is evoked by test items.

This observation emphasises that there are several mechanisms that might support selective retrieval processing. One possibility is that this is achieved by the engagement of selective retrieval-cue processing (cue bias: Anderson & Bjork, 1994; Bjork, 1989). According to this account, the differences between the ERPs elicited by new test words reflect processes that are engaged in order to ensure that the internal representations of the retrieval cues are such that they are more likely to interact with some memory representations than others, in each case increasing the likelihood that recollection will be restricted to information associated with only one of the two study conditions.

According to a second view, however, the locus at which these retrieval processes operate is on memory representations themselves, rather than on the retrieval cues that interact with those representations. By this account, which Anderson and Bjork (1994) have described as target bias, the processes set in train in response to new test items act directly on memory representations and influence their relative accessibility. Under this scenario, recollection of information associated with only one of two study tasks could come about because of inhibition of representations associated with the other task, excitation of representations associated with the representations defined as the target category, or a combination of these two possibilities. While it might be assumed that processes of this form are more likely to operate continuously throughout a retrieval task (Herron & Rugg, 2003a), the possibility that this class of processes operates at the level of individual test items cannot be ruled out.

A third account – the attention bias account – is also possible. According to this view, selective recollection does not come about because of processes that operate during the interaction between retrieval cues and memory representations. Rather, it occurs because only some of the products of retrieval are attended to. This account is similar to that offered for the absence of left-parietal old/new effects by Dywan et al. (2002, 1998, 2001), who focus on the allocation of attention to task-relevant material, and the way in which the ability to do so is impaired with increasing age. An important question for subsequent research is the accuracy or otherwise of these competing accounts of the mechanisms responsible for the effects reported here and in other ERP studies of episodic memory retrieval (Dywan et al., 2002, 1998, 2001; Herron &

Rugg, 2003a, 2003b). In a related vein, it will also be important to determine whether similar patterns of ERP old/new effects are obtained in tasks where there is an explicit requirement for participants to prioritise some kinds of encoded information at the expense of other kinds.

An additional important consideration that applies to the ERP data reported here stems from the fact that ERPs are sensitive to the probability structure of tasks: the amplitude of the P300 component of the electrical record is correlated negatively with the probability of stimulus occurrence, and is largest for task-relevant stimuli (Donchin & Coles, 1988; Sutton, Braren, Zubin, & John, 1965). These characteristics are pertinent, as according to the foregoing accounts targets are task-relevant in that recollection of information associated with targets is assumed to be a basis for task judgments, and the likelihood of a target response is substantially lower than that of a non-target/new response: an equal number of new, non-target and target stimuli were presented at test but responses to non-targets and new words were made on one key while responses to targets were made on another.

These facets of the design, alongside the fact that P300 is largest at Pz and peaks from 300 to 800 ms post-stimulus (Donchin & Coles, 1988), require consideration of whether the disparities between target and non-target ERP old/new effects can be explained by P300 modulations. The marked left-lateralisation and left parietal maximum of the target ERP old/new effects over the 500–800 ms epoch suggests that processes other than those underlying P300 are engaged during this epoch, since P300 shows no strong hemisphere bias. The fact, moreover, that the amplitude differences between the target and non-target ERPs are larger at left-hemisphere than at midline and at right-hemisphere locations suggests that P300 modulations are not responsible for all of the target/non-target disparity. In addition, in studies designed to assess the correspondence between P300 and the left-parietal ERP old/new effect, ERP old/new effects have been insensitive to variations in the proportions of old and new test items (Friedman, 1990; Herron et al., 2003; Smith & Guster, 1993), in particular if measurement of the parietal old/new effect is restricted to electrodes at parietal locations over the left hemisphere (Herron et al., 2003). In combination, these factors argue against the view that P300 modulations contribute significantly to the differences between the target and the non-target ERP old/new effects.

To summarise, the important aspects of the current findings are: (1) evidence that participants adopt distinct retrieval orientations when the information available for a target/non-target judgment is equivalent but target designation varies and (2) evidence that when targets and non-targets are distinguished only by the cognitive operations that were engaged at study, there is a marked difference between the retrieval processing associated with these two classes of test stimulus. These conclusions are the basis for the claim that the differences between the ERPs evoked by new words – the electrophysiological indices of retrieval orientation – reflect processes responsible for the strategic regulation of episodic retrieval by prioritising information associated with test items designated as targets.

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