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Controlled retrieval processing in recognition memory exclusion tasks

*Carina S. Fraser**, *Nicole C. Bridson*, *Edward L. Wilding*

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

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ABSTRACT

ERPs were acquired in the test phases of two memory tasks where three classes of word were presented: (i) words encountered in a study phase (studied words), (ii) words presented at test for the first time (new words), and (iii) new words repeated after a lag of 7–9 words (repeated test words). In Experiment 1, participants responded on one key to studied words (targets) and on a second to repeated test words (non-targets) as well as to new words. In Experiment 2, participants responded on one key to repeated test words (targets) and on a second key to new and studied words (non-targets). The likelihood of a correct response to a target was higher in Experiment 2 than in Experiment 1. In both experiments, the focus for the ERP analyses was on parietally distributed ERP old/new effects, which are assumed to index recollection. Reliable parietal old/new effects were obtained for targets as well as non-targets in Experiment 1, but for targets only in Experiment 2. This pattern of data is consistent with previous suggestions that, when the likelihood of recollecting information about targets is high, participants use the success or failure of an attempt to recollect information about targets as the basis for distinguishing between targets and all other classes of test word. The findings in these two experiments are informative because they: (i) generalise those obtained in previous work to a different exclusion paradigm, (ii) add emphasis to claims regarding the potential utility of this particular paradigm in studies where changes in memory control according to age are assessed, and (iii) highlight important considerations when behavioural data obtained in exclusion tasks are employed in order to make estimates of the relative contributions of recollection and familiarity to task performance.

1. Introduction

It is generally accepted that the human long term memory system requires control mechanisms in order to work effectively. This claim is based on evidence from neuropsychological studies (for reviews, see Moscovitch, 1992; Ranganath et al., 2003; Stuss et al., 1994) and computational models of memory retrieval (e.g., Johnson, 1992; Metcalfe, 1990; Norman and O'Reilly, 2003), as well as brain imaging studies (Rugg and Wilding, 2000; Wagner et al., 2001). It is also accepted that cognitive control can be exerted prior to as well as after *ecphory*—the interaction between a retrieval cue and a memory trace (Schacter et al., 1978; Semon, 1921; Tulving, 1983). Examples of control processes that operate prior to retrieval include two classes of retrieval set—retrieval mode and retrieval orientation (Rugg and Wilding, 2000; Wheeler et al., 1997). It is assumed that these retrieval sets are maintained

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* *Corresponding author*. Fax: +44 0 2920674858.
E-mail address: frasercs@cardiff.ac.uk (C.S. Fraser).

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tonically and that they influence the processes that are set in train when a memory cue is encountered. Examples of control processes that operate after or in conjunction with ecphory include those that operate on retrieved information in pursuit of task-relevant content (Johnson, 1992; Moscovitch, 1992).

One means of investigating how control of retrieval is implemented involves holding encoding conditions constant, and varying demands at the time of retrieval. In brain imaging studies, the dependent variables in experiments of this type include response accuracies and reaction times, alongside measures of neural activity. For example, contrasts between the event-related potentials (ERPs) elicited by test items on tasks requiring either old/new recognition memory judgements or context (source) judgements have been employed in order to make inferences about the time course and nature of pre-frontal cortical engagement in tasks that either do or do not require explicitly the recovery of detailed information from prior episodes (Kuo and Van Petten, 2006; Senkfor and Van Petten, 1998; Trott et al., 1997; Van Petten et al., 2000).

Inferences about the control of retrieval in tasks requiring recovery of contextual information have also been made on the basis of findings in ERP studies in which participants completed recognition memory exclusion tasks (Jacoby, 1991, 1998). In these tasks, participants are typically required to distinguish between new items (those presented at test for the first time) and two classes of old items, each having different study histories—for example, an equal number may have been spoken in a male/female voice in a prior encoding phase (Jacoby et al., 1992; Wilding and Rugg, 1997). At the time of the retrieval phase, participants are asked to respond on one key to items with one type of study history (often designated as 'targets') and on another key to new items as well as to items with different study histories ('non-targets').

The reason why the ERP findings in exclusion tasks have been interpreted in terms of retrieval control is due to the pattern of ERP old/new effects that have been obtained. ERP old/new effects are differences between the neural activity that are elicited by old and new test items to which correct judgements have been made (Rugg et al., 1994; Wilding et al., 2003). There are different old/new effects with distinct time courses, scalp distributions and cognitive correlates (for reviews, see Friedman and Johnson, 2000; Mecklinger, 2000; Rugg and Allan, 2000). The focus here is on the left-parietal ERP old/effect, which takes the form of a relatively greater positivity for old than for new items (Rugg et al., 1994). This effect onsets around 500 ms post-stimulus, has a duration of up to 1 s (e.g., Donaldson and Rugg, 1998; 1999) and is often, but not always, larger at left- than at right-hemisphere posterior scalp locations.

There is a relatively broad consensus that the effect indexes processes tied closely to recollection — recovery of qualitative detail about a prior study episode that can be used flexibly in service of task demands (Yonelinas, 2002). This consensus has been reached primarily on the basis of two broad sets of findings. First, the effect is attenuated markedly in patients with deficits associated primarily with recollection (Duzel et al., 2001; Mecklinger et al., 1998; Rugg et al., 1991; Smith et al., 1986; Tendolkar et al., 1999). Second, the effect has been shown to co-vary with the degree to which recollection is engaged across a number of different experiment manipulations (e.g., Duzel et al., 1997; Paller and Kutas, 1992; Smith, 1993; Wilding, 2000; Wilding and Rugg, 1996).

The critical ERP data in exclusion tasks that is of particular relevance here are the parietal ERP old/new effects associated with correct judgements to targets and to non-targets. In a number of recent studies, the magnitude of these effects has been markedly larger for targets than for non-targets (e.g., Czernochowski et al., 2005; Dzulkifli et al., 2006; Dzulkifli and Wilding, 2005; Herron and Rugg, 2003a,b; Hornberger et al., 2004; Wilding et al., 2005). If it is the case that this effect indexes recollection, then these data suggest that participants relied upon recollection of information about targets to complete the task to a markedly greater degree than on information about non-targets (Herron and Rugg, 2003a,b).

This pattern of data was first reported by Herron and Rugg (2003b), who conducted two experiments. In both, the encoding task associated with items denoted subsequently as non-targets was the same — generate a sentence incorporating a designated word. In Experiment 1, the encoding task for items denoted subsequently as targets required pleasantness ratings. In Experiment 2, the task was simply to read words aloud. The likelihood of correct target judgements was superior in Experiment 1, consistent with what would be anticipated given that the target encoding task in Experiment 1 required somewhat 'deeper' processing than that in Experiment 2 (Craik and Lockhart, 1972; Craik et al., 1998). The accuracy of non-target judgements was equivalent in the two experiments.

Left-parietal ERP old/new effects were reliable for targets and for non-targets in Experiment 2, and for targets only in Experiment 1, despite the fact that non-targets in the two experiments were associated with the same encoding operations. Given the link between the left-parietal ERP old/new effect and recollection, these data suggest that participants relied to a greater extent on recollection of information about non-targets in Experiment 2 than in Experiment 1.

In offering an explanation for this, Herron and Rugg (2003b) started from the observation that completing successfully the binary distinction between targets and non-targets could be accomplished using more than one strategy. One approach, as described above, is to attempt to recollect information about targets and non-targets in order to complete the task (cf. Jacoby, 1998). An alternative, however, is to attempt to recollect information about targets only and use the success or failure of this operation as the basis for a target/non-target judgement. Herron and Rugg (2003b) observed that the latter strategy increases in utility along with the likelihood of recovery of task-relevant information about targets.

This formed the basis for their explanation of the findings. They proposed that when the likelihood of recovering qualitative information about targets is high, a reasonable strategy is to use the presence or absence of qualitative information about targets as the diagnostic for the binary judgement that is required in the exclusion task. When the likelihood of recovering qualitative information about targets declines, so does the utility of this strategy. Under these circumstances, a better strategy is to depend upon recollection of information about non-targets as well as targets. Insofar as the magnitude of the left-parietal ERP old/new indexes recollection, this account explains the data described above — a more marked disparity between the sizes of the left-parietal ERP old/new effects for targets and non-targets when the likelihood of a correct target judgement is high than when it is somewhat lower.

While the initial conclusions drawn by Herron and Rugg (2003b) can be criticised because of the confound between the encoding tasks associated with targets and non-targets across the two experiments, and the fact that there was no explicit measure of the memorability of non-targets for the participants completing the ERP studies, their explanation fits with subsequent findings in designs without these confounds (in particular, see Dzulkifli et al., 2006; Dzulkifli and Wilding, 2005; Herron and Rugg, 2003a; Wilding et al., 2005). Indeed, it is striking that, at least under some circumstances, left-parietal ERP old/new effects associated with correct judgements to non-targets are attenuated markedly, even when the likelihood of recollecting information about non-targets is high (e.g., Dzulkifli and Wilding, 2005). Correspondingly, when the accuracy of target judgements is reduced, reliable left-parietal ERP old/new effects for targets as well as for non-targets have been obtained (Dzulkifli et al., 2006; Herron and Rugg, 2003b; Wilding et al., 2005).

One of the implications of the theoretical account given above is that, under some circumstances, people can exert considerable control over whether or not information is recollected, and this implication in turn suggests that ERPs acquired in episodic retrieval tasks may be a useful functional tool for determining; (i) the conditions under which this selectivity can be achieved (for discussion, see Dzulkifli and Wilding, 2005; Herron and Rugg, 2003a; Hornberger et al., 2004), and (ii) the ways in which control of retrieval varies according to subject variables such as age and focal brain damage.

The two experiments reported here were designed in order to provide data germane to both of these issues. With respect to the first, the broad utility of the acquisition of ERPs alongside behavioural measures as a means of determining when and how control of retrieval is implemented depends in part upon the extent to which comparable patterns of selective attenuation of left-parietal ERP old/new effects can be obtained across tasks with somewhat different demands at the time of retrieval than those described above. With respect to the second issue, it has been argued that the designs of the exclusion tasks described here are not well-suited for implementation in studies where the motivation is to assess changes in performance across different populations (Graf and Komatsu, 1994). Concerns have been raised about whether changes in task performance across different populations on these types of exclusion task reflect genuine differences in the memory processes necessary to complete the tasks. An alternative is that changes in performance come about because some populations have greater difficulty understanding and adhering to the task instructions than do others (Graf and Komatsu, 1994; Jennings and Jacoby, 1997).

This criticism cannot be levelled at a variant of the exclusion procedure first introduced by Jennings and Jacoby (1997), in a study in which they contrasted task performance for young and for older adults. All study items were subjected to the same encoding operations, and in the subsequent retrieval task, a proportion of new (unstudied) test items were repeated after different lags (hereafter repeated test items). Either studied items or repeated test items can be designated as targets in this design, although Jennings and Jacoby (1997) reported findings only for the condition in which studied items were targets. Importantly, they argued that this task was well-suited to assessments of changes in memory processing according to age by virtue of the introduction of repeated test items. By varying lag, an assessment of changes in memory accuracy with time is possible, and in addition, concerns over differences across groups in following task instructions can be ruled out by demonstrating high and comparable levels of response accuracy across groups at short lags (Jennings and Jacoby, 1997).

The two experiments described here employed this study/repeated test item exclusion procedure since it provides a means of assessing the generality of the findings in previous ERP exclusion tasks by employing a somewhat different design, and in addition it does so in a paradigm that is well-suited to assessing changes in memory control operations with age. In both experiments, the encoding task – read words aloud – was constant. In Experiment 1, studied words were designated as targets, whilst in Experiment 2, repeated test words were designated as targets. Study list lengths and repeated test item lags were employed which ensured that the likelihoods of correct responses at test were superior in Experiment 2, thereby permitting a contrast across experiments of the ways in which electrophysiological signatures of recollection vary according to target accuracy. If the findings reported above extend to this version of the exclusion procedure, then the degree of attenuation of non-target parietal ERP old/new effects in Experiment 2 should be greater than that in Experiment 1. These experiments are designed to investigate the generality of the ERP findings obtained in the experiments described above, as well as provide a means of assessing further (cf. Dywan et al., 1998, 2001, 2002) the potential utility of this paradigm as a vehicle for investigating age-related changes in the control of episodic retrieval.

2. Results

2.1. Behavioural data

Table 1 shows reaction times (RTs) and probabilities of correct responses to targets, non-targets and correct rejections in Experiments 1 and 2. In each experiment, the likelihood of a target response to a target was reliably greater than the likelihood of a target response to a non-target or to a new test item ($t > 10.00$, $p < 0.001$ in each case). Differences in response accuracy across experiments were assessed in an unequal groups ANOVA with factors of experiment and category (correct responses to targets, non-targets and new test words). The analysis revealed an interaction between these factors ($F(1.1,35.3) = 17.14$, $p < 0.001$)[1] and Bonferroni correct unpaired t-tests (adjusted $\alpha = 0.017$) revealed that only the accuracy of target responses differed reliably across experiments, being superior in Experiment 2 ($t(21.95) = 4.47$, $p < 0.01$). The across-experiment RT analysis for correct responses revealed an experiment × category interaction ($F(1.5,48.9) = 10.84$, $p < 0.001$). Unpaired Bonferroni corrected t-tests across each

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[1] In this and in all subsequent ANOVAs, the Geisser–Greenhouse correction was applied where necessary. Corrected degrees of freedom are shown in the text.

Table 1 – Probabilities of correct responses (*p*[correct]) and reaction times (RT) to targets, non-targets and new words in Experiments 1 (target = studied, non-target = repeated test) and 2 (target = repeated test, non-target = studied)

	Target	Non-target	New
Exp 1.			
p[correct]	0.62 (0.16)	0.90 (0.07)	0.91 (0.12)
RT	948 (414)	853 (366)	914 (403)
Exp 2.			
p[correct]	0.82 (0.08)	0.84 (0.07)	0.97 (0.02)
RT	874 (217)	899 (300)	775 (225)

SDs in brackets.

experiment, however, revealed no reliable differences between the individual response categories. The likely reason for the interaction is the fact that there is a numerical RT advantage for correct rejections as well as for targets in Experiment 2, and an advantage for non-targets in Experiment 1.

2.2. ERP data

2.2.1. Parietal ERP old/new effects

In keeping with the focus outlined in the Introduction section, the ERPs were subjected initially to directed analyses at parietal locations in order to assess sensitively the ERP old/new effects for targets and for non-targets in the two experiments. These analyses incorporated initially data from P5/P6 and P3/P4 over the 500–800 ms time window, including factors of response category, hemisphere and site. The initial analyses were completed within experiment, and then analyses on subtraction waveforms (mean amplitudes associated with correct rejections subtracted from targets and non-targets, respectively) were completed across experiments.

Fig. 1 shows the ERPs elicited by correct responses to targets, non-targets and correct rejections at parietal sites in Experiment 1 (upper panel) and Experiment 2. From approximately 500 to 800 ms in Experiment 1, ERPs associated with targets and non-targets are more positive-going than those associated with correct rejections. This is true only for ERPs associated with targets in Experiment 2. The initial analysis within each experiment revealed main effects of category (Exp. 1: $F(1.6,23.6) = 22.61$, $p < 0.001$; Exp. 2: $F(1.4,24.0) = 31.69$, $p < 0.001$) and a category × site interaction for Experiment 2 only ($F(1.4,23.8) = 9.68$, $p < 0.01$).

These analyses were followed up by all possible paired contrasts. Table 2 (upper portion) shows the outcomes of these: except for the ERPs elicited by non-targets in Experiment 2, the ERPs elicited by all other classes of old test item were reliably more positive-going than those elicited by correct rejections. The interactions and marginal interactions with site for the analyses incorporating correct rejections occur because the effects are largest at the sites closest to the midline (P3/P4). In keeping with this pattern of data, an unequal groups ANOVA (carried out on mean

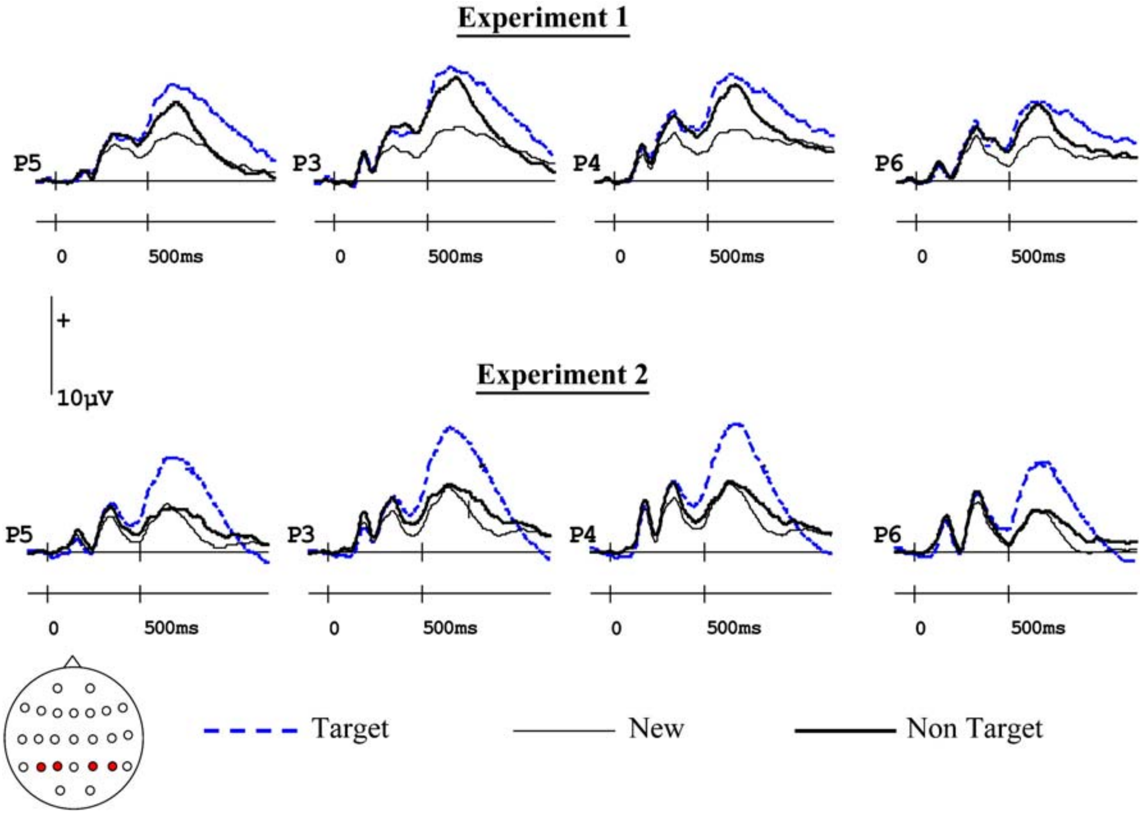

Fig. 1 – Grand average ERPs associated with correct judgements to targets, non-targets and new words at parietal sites (P3/P4, P5/P6) in Experiment 1 (upper panel) and Experiment 2.

Table 2 – The outcomes of the paired contrasts between the mean amplitudes associated with correct responses to targets, non-targets and new words across parietal sites (P3/P4, P5/P6) for Experiments 1 and 2 over the 500–800 ms time window (upper portion) and 800–1000 ms window

Effect	*df*	Experiment 1	*df*	Experiment 2
500–800 ms				
Target vs New				
RC	1,15	65.50***	1,17	39.76***
RC × SI	2,30	3.64$^{\bullet}$	2,34	11.56**
Non-target vs New				
RC	1,15	21.78***	1,17	ns
RC × SI	2,30	3.32$^{\bullet}$	2,34	ns
Target vs Non-target				
RC	1,15	3.97$^{\bullet}$	1,17	31.38***
RC × SI	2,30	ns	2,34	12.35**
800–1000 ms				
Target vs New				
RC	1,15	27.80***	1,17	16.92***
RC × SI	2,30	ns	2,34	ns
Non-target vs New				
RC	1,15	ns	1,17	10.79**
RC × HM	1,15	4.88*	2,34	ns
Target vs Non-target				
RC	1,15	20.65***	1,17	8.643**
RC × SI	2,30	ns	2,34	ns

RC = response category, SI = site, *df* = degrees of freedom. *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$, $^{\bullet}$ = $p < 0.1$, ns = non-significant.

amplitudes obtained from the subtraction scores as described above) revealed an experiment × response category interaction ($F(1,32) = 5.45$, $p < 0.05$).

Table 2 also shows that, at these electrode sites in this time window, the ERPs elicited by targets are reliably more positive-going than those elicited by non-targets in Experiment 2 and that this effect approaches significance in Experiment 1. The magnitudes of the differences between these classes of ERPs at these electrode sites appear to increase later in the recording epoch, and in light of this, the same analysis strategy for the parietal data for the 500–800 ms epoch was employed on mean amplitudes extracted from the 800–1000 ms epoch. This later epoch captures the apparent differences between the magnitudes of the ERP old/new effects for targets as well as for non-targets in the two experiments, whilst not extending into the time window in which the ERPs elicited by targets attracting correct judgements become more negative-going than those elicited by correct rejections and non-targets (see Fig. 1, lower panel).

The initial separate analyses at parietal sites for each experiment in this time window revealed main effects of category (Exp. 1: $F(2,30) = 18.79$, $p < 0.001$; Exp. 2: $F(2,34) = 13.19$, $p < 0.001$). Table 2 (lower portion) shows the outcomes of the paired follow up analyses and demonstrates that, in both experiments, ERPs elicited by targets were reliably more positive-going than those elicited by non-targets, which in turn were more positive-going than those elicited by new test words. The interaction for the non-target/new contrast in Experiment 1 reflects the fact that the greater relative positivity associated with non-targets is larger at right than at left-hemisphere scalp locations. The analysis across experiments on subtraction scores (mean amplitudes associated with correct rejections subtracted from those for targets and non-targets, respectively) revealed only that the target old/new effects were reliably larger than the non-target effects. The scalp distributions of the ERP old/new effects for targets and for non-targets in Experiments 1 and 2 for the 500–800 and 800–1000 ms epochs are shown in Fig. 2, which also shows the differences for the two experiments between the ERPs elicited by targets and by non-targets attracting correct judgements.

2.2.2. *Analyses of scalp distributions*

The scalp distributions of the target and non-target ERP old/new effects in both experiments were submitted to ANOVA. This analysis was carried out in order to determine whether there was statistical evidence that the scalp distributions of the old/new effects varied according to category or time window (for discussion, see Urbach and Kutas, 2002; Urbach and Kutas, 2006; Wilding, 2006). In order to assess this possibility rigorously via ANOVA, it is necessary to re-scale the data prior to analysis in order to avoid confounding differences in the magnitudes of effects over the variable of interest with differences in the shapes (topographies) of the effects (McCarthy and Wood, 1985).

This analysis was conducted over re-scaled difference scores obtained by subtracting, within each experiment, the mean amplitudes associated with correct rejections from those associated with correct responses to targets and to non-targets, respectively. The analysis included data from all 25 scalp locations from which ERPs were acquired. The data were re-scaled using the max–min method (McCarthy and Wood, 1985), and the analysis included the factors of experiment, category (target/non-target)[2], epoch (500–800 ms, 800–1000 ms) and site. The analysis revealed no reliable effects involving category or time window.

2.2.3. *Early ERP old/new effects*

An additional set of directed analyses was completed for the data from the 300–500 ms time window. This approach was motivated in part by the fact that, at anterior sites in this post-stimulus epoch, it has been proposed that ERPs are sensitive to item familiarity (Curran et al., 2006; Rugg et al., 1998). It has also been demonstrated that this anteriorly distributed modulation is functionally dissociable from a posteriorly distributed modulation with a similar time course (Azimian-Faridani and Wilding, 2006; Rugg et al., 1998). It has been proposed that this posteriorly distributed modulation indexes implicit memory, a view supported by the fact that the modulation is sensitive only to the old/new status of test items, rather than to the accuracy of the judgements that old and new items receive (Rugg et al., 1998; although see Rugg et al., 2000).

The analysis for this time window was restricted to the data from Experiment 1 as only in this experiment were there

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[2] The analysis of scalp distributions included data from the 500–800 ms epoch for non-targets in Experiment 2 because, despite there being no reliable old/new effects for this category in the directed analysis at parietal locations, there were reliable old/new effects at scalp locations that were not the primary focus of interest in this study.

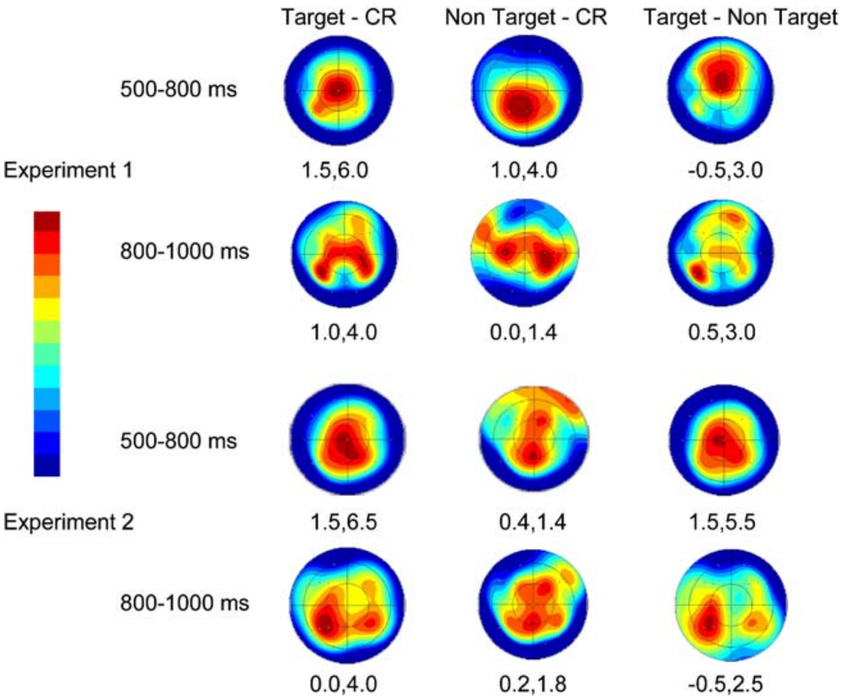

Fig. 2 – Scalp distributions of the ERP old/new effects for targets and non-targets in Experiments 1 and 2. The data are shown for two post-stimulus epochs: 500–800 and 800–1000 ms. The maps were computed from scores obtained by subtracting mean amplitudes from the ERPs evoked by new items from targets and non-targets, and subtracting non-targets from targets. The paired values below each map denote the minima and maxima of the amplitude differences between response categories, which can be interpreted relative to the colour bar on the left-hand side of the figure.

sufficient incorrect responses to targets to permit formation of reliable averaged ERPs. Given the functional accounts described in the previous paragraph, an analysis restricted to ERPs elicited only by correct responses cannot speak to issues regarding the functional significance of these early ERP old/new effects with anterior and posterior foci, respectively. The relevant data for the analyses reported here can be seen in Fig. 3, which shows ERPs elicited at frontal and posterior scalp sites for all four conditions of interest: correct responses to non-targets and new test words, as well as correct and incorrect responses to targets.

In order to investigate these early ERP old/new effects sensitively, and in keeping with the approach taken for isolating the neural activity underlying the left-parietal ERP old/effects, separate analyses were undertaken at mid-frontal (F3, Pz, F4) and at posterior (P3, Pz, P4) electrode locations. The initial global analyses including data from all four conditions revealed main effects of condition (anterior: $F(2.3,34.8) = 3.52$, $p < 0.05$; posterior: $F(2.0,29.9) = 5.10$, $p < 0.01$). The follow up analyses comprised all possible paired contrasts and revealed that the mean amplitudes associated with targets and with non-targets were statistically indistinguishable, but were both reliably more positive-going than those elicited by correct rejections at anterior as well as at posterior sites (Targets anterior: $F(1,15) = 6.46$, $p < 0.05$; Non-targets anterior: $F(1,15) = 9.94$, $p < 0.01$; Targets posterior: $F(1,15) = 8.30$, $p < 0.05$; Non-targets posterior: $F(1,15) = 38.82$, $p < 0.01$). ERPs elicited by incorrect responses to targets were reliably more positive-going than those elicited by correct rejections at posterior sites only ($F(1,15) = 15.52$, $p < 0.01$). The other contrasts involving incorrect responses to targets revealed no reliable effects, although at anterior sites the relatively greater positivity associated with correct responses to targets as well as non-targets approached significance ($p < 0.1$ in both cases).

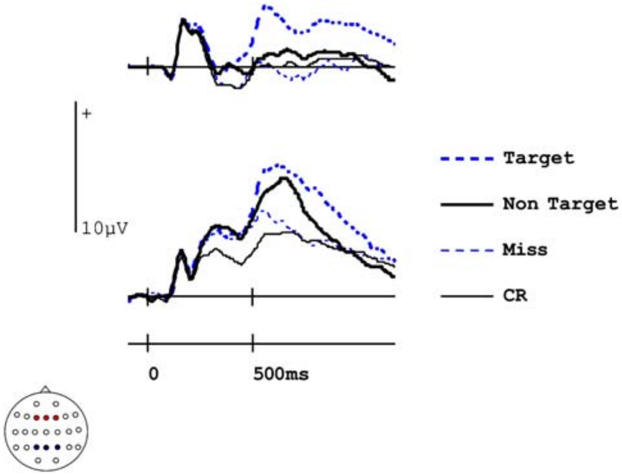

Fig. 3 – Grand average ERPs elicited by targets, non-targets, misses and correct rejections (CR) at frontal (upper panel) and parietal sites, incorporating data collapsed separately across frontal (F3, Fz, F4) and posterior (P3, Pz, P4) locations in Experiment 1.

3. Discussion

The principal focus in these two experiments was on the parietal ERP old/new effects that were obtained. There were also differences according to condition, however, in the 300–500 ms time period. We address these findings briefly, before turning to the data that are relevant to the question of the conditions under which selective recovery of task-relevant contextual information is accomplished.

It has been proposed that two functionally distinct ERP old/new effects, with fronto-central and parietal maxima respectively, are evident in the 300–500 ms post-stimulus time window (Azimian-Faridani and Wilding, 2006; Rugg et al., 1998). Rugg et al. (1998) linked the posterior effect with implicit memory, since in their study the effect differentiated only the old/new status of test items and not the accuracy of memory judgements. The data shown in Fig. 3 are consistent with this account, as at posterior sites correct responses to targets and non-targets, as well as incorrect responses to targets, were reliably more positive-going than correct rejections. The ERPs at these posterior locations thus index the old/new status of test items but do not predict the accuracy of memory judgements. This pattern of data fulfils one criterion for being an index of implicit memory, but in this study, as in all prior studies to date where this has been demonstrated, the effect has not been accompanied by a behavioural index of implicit memory (Azimian-Faridani and Wilding, 2006).

Rugg et al. (1998) also speculated that an anteriorly distributed modulation occurring in the 300–500 ms time window indexes familiarity. Although the initial support for this proposal was not compelling (Rugg and Allan, 2000), the findings in subsequent studies are consistent this account (in particular, see Azimian-Faridani and Wilding, 2006; Woodruff et al., 2006; for a comprehensive review, see Curran et al., 2006). The pattern of data obtained here is also in line with this proposal because at anterior sites only, the ERPs elicited by targets and non-targets that attracted correct responses were more positive-going than those elicited by correct rejections. This pattern of data is consistent with the view that the frontal modulation indexes a process that supports explicit memory judgements, of which familiarity is one candidate (for some caveats, see Voss and Paller, 2006; Yovel and Paller, 2004).

We turn now to the ERP data acquired from 500 to 1000 ms post-stimulus, focusing on the ERPs elicited at parietal scalp locations. The 500–800 ms epoch is one in which parietal ERP old/new effects are typically assessed (Friedman and Johnson, 2000; Mecklinger, 2000; Wilding et al., 2003), and in this time period the ERP old/new effects were reliable for targets in both experiments, and for non-targets in Experiment 1 only. Targets were denoted as studied words in Experiment 1, and as repeated test words in Experiment 2. There was a trend for the parietal ERP old/new effect for targets in Experiment 1 to be larger than the effect for non-targets (for discussion of reasons for this small divergence, see Dzulkifli et al., 2006; Dzulkifli and Wilding, 2005).

At the same scalp locations, there were reliable ERP old/new effects for targets in the 800–1000 ms time window, as well as for non-targets in Experiment 2. In both experiments in this time window, moreover, there was a relatively greater positivity for targets than for non-targets, characterised by a common and focal positivity at left-parietal scalp locations, as Fig. 2 shows. The scalp distributions of the reliable ERP old/new effects in this time window differ somewhat from the distributions of the effects in the 500–800 ms time window, but the outcome of the analysis of the scalp distributions of the ERP old/new effects over the 500–800 and 800–1000 ms epochs provided no statistical support for the view that different processes were engaged at different points in time.

If the somewhat lateralised parietal differences between these conditions are indices of the extent to which recollection was engaged, then the pattern of effects is consistent with the view that the extent to which recollection of target over non-target information was prioritised was somewhat greater in Experiment 2 than in Experiment 1. This example of differential attenuation of non-target parietal old/new effects across experiments replicates findings in four other cases (Dzulkifli et al., 2006; Dzulkifli and Wilding, 2005; Herron and Rugg, 2003a,b; Wilding et al., 2005). In keeping with the findings in each of these pairs of experiments, the differential attenuation of the ERP old/new effects for non-targets that is reported here occurred across a pair of experiments in which the likelihood of a correct target judgement was lower in one than in the other. In all cases, the greater attenuation of non-target old/new effects relative to the respective target effects occurred in the experiment within each pair in which the likelihood of a correct target judgement was higher. These findings are therefore consistent with the view that participants adopt strategies in exclusion tasks where the extent to which recollection of information of targets is likely determines the extent to which recollection of information about non-targets will be prioritised (Herron and Rugg, 2003b).

One objection to this account, however, stems from the observation that, in comparison to the majority of ERP exclusion tasks studies that have been designed in order to address similar issues regarding the strategic control of retrieval, the likelihood of a target response is somewhat lower in this study by virtue of the experiment designs. In the majority of previous studies described above, there were an equal number of new items, targets and non-targets (Dzulkifli et al., 2006; Dzulkifli and Wilding, 2005; Herron and Rugg, 2003a,b; Wilding et al., 2005). In these two experiments, whilst there were the same numbers of targets and non-targets, there were twice as many unstudied words shown at test.

This item type imbalance means that, in these experiments, the probability of encountering a target is somewhat lower than in other relevant studies. The percentage of target responses (taking into account correct and incorrect responses to all classes of test stimuli) was 23% in Experiment 1, and 25% in Experiment 2. The reason why these considerations are relevant here is because the P300 ERP component is particularly sensitive to frequencies of stimulus occurrence (Donchin, 1981; Donchin and Coles, 1988; Friedman et al., 2001; Horst et al., 1980; Squires et al., 1975). The component typically has a time course that overlaps with the time course of the parietal ERP old/new effect and is more positive-going for lower probability classes of item (Donchin and Coles, 1988).

These considerations raise the possibility that the markedly greater relative positivity for correct target than for non-target responses in Experiment 2 is not due to processes that are involved in processing selectively mnemonic information relevant to targets. Rather, the differences may be due to the fact that studied items (non-targets in Experiment 2) elicit little or no parietal ERP old/new effects, and the positive-going old/new effect for studied items in Experiment 1 (where those items were designated as targets) is simply a consequence of the response probability imbalance (for related comments, see Bridson et al., 2006).

This alternative account of the ERP data draws some support for the fact that, at posterior scalp locations, there was no statistical evidence for reliable left lateralisation of the posteriorly distributed ERP old/new effects. Insofar as the left-parietal ERP old/new effect has a left hemisphere bias that is not characteristic of the P300 (Azimian-Faridani and Wilding, 2006; Rugg and Allan, 2000), then the absence of a reliable hemisphere bias is consistent with a response probability account of these aspects of the data.

Fig. 2 shows, however, a consistent trend across conditions for there to be a left hemisphere bias in the ERP old/new effects for targets and for non-targets from approximately 500 ms post-stimulus onwards. There are two additional and compelling reasons, moreover, for rejecting the response probability account of the data. First, ERP old/new effects for words encoded in the same task employed here (read aloud) have been reported in exclusion tasks where the words encoded under these conditions were designated as targets, where the study–test interval was longer than the interval in these experiments, and where the proportions of targets, non-targets and new test words were equal (Herron and Rugg, 2003b).

Second, Herron et al. (2003) conducted an ERP study in which old/new recognition memory judgements were required, and where, across blocks, the ratios of new to old test items were 3:1, 1:1 and 1:3. Over the 500–800 ms period at left-parietal scalp sites, the positive-going ERP old/new effects that were obtained were of equal magnitude across these different ratios of old and new words. The 1:3 old/new ratio is directly comparable to the ratio of targets to the other (combined) classes of test stimuli in Experiments 1 and 2 (for prior work relevant to the invariance of parietal old/new effects across other ratios of old and new test items, see Friedman, 1990; Rugg and Nagy, 1989; Smith and Guster, 1993). These observations argue against a response probability account of the data in these experiments, and further support for this view stems from the fact that qualitatively similar findings to those in Experiment 1 were reported recently by Bridson et al. (2006) where studied words designated as targets comprised 40% of the test stimuli (see Experiment 1 in their manuscript). In combination, the invariance of ERP old/new effects across these studies, and the correspondences between the data in those studies and the findings reported here, suggests that an interpretation of the data in Experiments 1 and 2 in terms of strategic retrieval processing is reasonable.

If this supposition is accepted, then these findings also demonstrate the utility of applying this paradigm in different populations in whom process-specific memory impairments may be present. As outlined in the Introduction section, this paradigm has some advantages over the exclusion procedure in which targets and non-targets are both presented in a prior study phase (Graf and Komatsu, 1994; Jennings and Jacoby, 1997). One advantage of the exclusion procedure adopted here is the opportunity to vary lags in order to accomplish two goals. First, the use of very short repetition lags at test permits an assessment of whether different groups are able to understand task instructions equally well (e.g., Jennings and Jacoby, 1997). Second, the use of varying lags in different populations provides a means of contrasting measures of neural activity across lags at which response accuracy is equated. Dywan et al. (2002; see also 1998; 2001) acquired ERPs time-locked to test stimuli in a very similar exclusion task to the one employed here. Repeated test items were designated as non-targets and were presented at the same lag for both groups. The accuracy of non-target responses was lower for the older participants (cf. Jennings and Jacoby, 1997), and at posterior sites there was little evidence for parietal old/new effects for targets or non-targets in the older group, a finding that is likely due in part to the low levels of target/non-target discrimination in that group. By equating performance across different lags for different age individuals, however, it should in principle be possible to ascertain whether the selective control of retrieval exerted by young adults can also be exerted, under comparable circumstances, by older adults.

At the same time, however, as highlighting the utility of acquiring ERPs alongside behavioural measures in appropriately titrated exclusion paradigms as a means of exploring changes in retrieval control according to age, these ERP findings introduce a note of caution with respect to how inferences about the reasons for changes in response accuracy with age can be made on the basis of behavioural data acquired in exclusion and ‘inclusion’ tasks. As noted in the Introduction section, Jennings and Jacoby (1997) reported their findings in an exclusion task in which studied words were non-targets. The same participants completed an ‘inclusion’ task, where ‘old’ responses were to be made to both studied and repeated test words. The performance of older adults was inferior to that of younger adults on both tasks.

Jennings and Jacoby (1997) employed the process-dissociation procedure (PDP: Jacoby, 1991, 1998) in order to estimate the contributions that recollection and familiarity made to task performance and concluded that the changes in performance with age were due to less availability of recollection form older than for younger adults. All details of the PDP are not critical here, but a key assumption that underlies the PDP is that participants rely upon recollection in order to reject successfully non-targets (Jacoby, 1991). Electrophysiological support for this interpretation would, therefore, comprise reliable parietal ERP old/new effects associated with correct judgements to non-targets (Herron and Rugg, 2003b). The ERP data reported here, and elsewhere in different exclusion procedures (in particular, see Dzulkifli and Wilding, 2005; Herron and Rugg, 2003b), suggest that, at least for some levels of response accuracy, the assumption that recollection is the basis for non-target judgements is questionable, which in turn calls into question the accuracy of estimates derived from the process-dissociation procedure.

Finally, one question not addressed by the findings presented here is whether, for repeated test words, recollection of task-relevant information can be controlled. The reason why these data do not speak to this issue is because these items were designated as non-targets in the condition where target accuracy was relatively low (Experiment 1). According to the foregoing account, under these circumstances, there is little or no incentive to focus primarily on recovery of information associated with targets as a good diagnostic for task judgements. It is possible, therefore, that, by virtue of their relatively recent occurrence, selective recovery of information about targets cannot be accomplished when repeated test words are non-targets. To test this possibility, it will be necessary to alter Experiment 1 in order to increase the likelihood of a correct target response. Two ways to accomplish this are to shorten study and test list lengths, and change the encoding task that is required for study items. At issue here are the boundary conditions under which recollection of some kinds of information can be prioritised at the expense of others. Delineating further the conditions under which cognitive control over retrieval processing can be exerted is a precursor to establishing how such control operations vary according to variables including age, disease state and pharmacological interventions.

4. Experimental procedures

Due to the similarities between the designs of the two experiments, they are described jointly, with differences between the two noted where appropriate.

4.1. *Participants*

Nineteen participants completed Experiment 1; the average age was 21 years (range 18 to 30). The data from 3 participants were discarded due to excessive EOG artefact. Of the remaining 16 participants, 14 were female. Eighteen participants completed Experiment 2; the average age was 20 years (range 18 to 23) and 13 participants were female. All were right-handed native English speakers. No participants were taking neuroleptic medication at the time of testing or reported a history of mental illness. All were paid at a rate of £7.50/h and gave informed consent prior to commencing the experiments. No participant completed both experiments.

4.2. *Materials and design*

Across both experiments, words were taken from the MRC psycholinguistic database (frequency range = 1–7 occurrences per million, length = 4–9 letters: Coltheart, 1981). These were presented in white letters on a black background in upper case on a computer monitor placed 1 m from participants. The stimuli subtended maximum visual angles of 5° (horizontal) and 0.6° (vertical). In Experiment 1, 400 critical words were split initially into eight equal groups of 50 words. One complete task list comprised two study–test cycles, and each study–test cycle contained words from four of the eight 50-word groups. No groups of words were employed in both study–test cycles. There were 70 words in each study cycle; one complete study list and 20 fillers selected at random from a second list. The remaining 30 items from the second list were not presented during the experiment. The fillers were presented only at study, and, in both experiments, were placed at the end of the study list. There were 150 words in each test cycle; 50 words presented at study, 50 unstudied (new) words and a further 50 new words which were repeated once after 7–9 intervening words. The numbers of words re-presented after lags 7, 8 and 9 were approximately equal within blocks and equated across blocks. In addition, 5 fillers were placed towards the end of each test list in each cycle in order to ensure that the final repeating words fell within the 7–9 word repeat interval. No words appeared in both study–test cycles. The groups of words were rotated across study–test cycles, as well as study and test lists, so that, across complete task lists, all words were presented (within each cycle) at study as well as at test, at test once, at test twice, and were included on the list of fillers from which fillers were selected, as described above. This procedure resulted in the preparation of eight complete task lists. In total, participants saw 70 stimuli in each study phase and 205 stimuli in each test phase.

In Experiment 2, each task list contained the same number of stimuli as in Experiment 1. One departure across experiments, however, was that, rather than being drawn at random from a separate initial 50-word list, in Experiment 2, the same 40 filler items (20 per cycle) were employed at study in each complete task list. This procedural change meant that there were only 340 words employed in Experiment 2. These were split randomly into six groups of 50 words and two groups of 20 filler words. Three of the six 50-word lists were assigned randomly to the first study–test cycle, and the other three to the second cycle. Rotating words across study and test lists so that all words appeared at study as well as at test, at test once only, and at test twice, resulted in the creation of six complete task lists. Fillers appeared equally often in the first and second study cycles. The total number of stimuli seen by participants in Experiment 2 was the same as in Experiment 1.

4.3. *Procedure*

Prior to commencing either experiment, participants were informed that they would be presented with a series of words on the computer screen. The number of study–test cycles was not stated. At study, participants were asked to read each word aloud. Each study trial began with an asterisk (*), which was displayed for 1000 ms and followed by a blank screen (100 ms), after which the study word was presented for 300 ms. The asterisk signalling the start of the next trial appeared 2000 ms later. Each test trial also began with an asterisk (1000 ms), followed by a blank screen (100 ms) before presentation of the test item, which was visible for 300 ms. The screen remained blank for 1000 ms following the response of the participant, after which the asterisk signalling the start of the next trial appeared. Participants made responses with their left and right thumbs. The thumbs required for the binary test judgement were balanced across participants and all participants were encouraged to respond weighting speed and accuracy equally. Responses slower than 4000 ms and faster than 300 ms were treated as errors and were discarded from subsequent analyses. There were no trials to reject in Experiment 1 according to these criteria, and less than 1% of trials in Experiment 2.

In Experiment 1, participants were asked to press one key if they thought the word had been presented previously in the study phase, and a second key for all repeated test and new words. In Experiment 2, participants were asked to press one key if they thought the word was a repeated new test word, and a second key for all other test words. In both experiments, instructions for the test phases were given prior to the first study phase, as well as immediately before each test phase.

4.4. EEG acquisition

These procedures were identical in the two experiments. EEG was recorded from 25 silver/silver chloride electrodes at midline sites (Fz, Cz, Pz) and left/right hemisphere locations (FP1/FP2, F7/F8, F5/F6, F3/F4, T3/T4, C5/C6, C3/C4, T5/T6, P5/P6, P3/P4, O1/O2: Jasper, 1958). Additional electrodes were placed on the mastoid processes. EEG data (range 0.03–40 Hz; sampling rate 200 Hz) were acquired referenced to Fz and re-referenced off-line to the algebraic mean of the signal at the two mastoids. Data from Fz were recovered. The data were epoched into periods of 1280 ms (256 data points), including a 100 ms pre-stimulus baseline, relative to which all mean amplitudes were measured. EOG was recorded from above and below the right eye (VEOG) and on the outer canthi (HEOG). Epochs containing large EOG artefact were rejected, as were epochs containing A/D saturation or baseline drift exceeding ±80 μV. Other blink artefacts were corrected using a linear regression estimate (Semlitsch et al., 1986). A 7-point binomially weighted smoothing filter was applied prior to analysis.

Averaged ERPs were formed for correct judgements to target, non-target and new items (correct rejections) for each participant in each experiment, as well as for incorrect responses to targets (misses) in Experiment 1. There were insufficient incorrect responses to any class of item in Experiment 2 to permit formation of reliable averaged ERPs. Participants were excluded if they did not contribute at least 16 artefact free trials to each of these response categories (cf. Wilding and Rugg, 1996). In Experiment 1, the mean numbers of trials per response category were 50, 74, 158 and 34 trials for correct responses to targets, non-targets and correct rejections and for incorrect responses to targets. In Experiment 2, the mean numbers of trials per category for correct responses were 47, 51 and 116, respectively.

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