ARTICLE IN PRESS

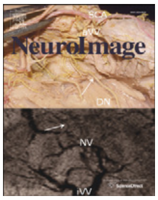
YNIMG-07934; No. of pages: 9; 4C: 5, 6

NeuroImage xxx (2011) xxx–xxx

Contents lists available at ScienceDirect

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg



Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory

Kristine A. Wilckens [a,b,c,*], Joshua J. Tremel [a,b], David A. Wolk [d], Mark E. Wheeler [a,b,c]

[a] Department of Psychology, University of Pittsburgh, Pittsburgh, PA, USA
[b] Learning Research and Development Center, University of Pittsburgh, Pittsburgh, PA, USA
[c] Center for the Neural Basis of Cognition, University of Pittsburgh, Pittsburgh, PA, USA
[d] Department of Neurology, University of Pennsylvania, Philadelphia, PA, USA

ARTICLE INFO

Article history:
Received 9 July 2010
Revised 13 December 2010
Accepted 22 December 2010
Available online xxxx

Keywords:
Retrieval preparation
Retrieval mode
Task-set
ERPs
Recollection
Familiarity

ABSTRACT

Successful memory retrieval depends not only on memory fidelity but also on the mental preparedness on the part of the subject. ERP studies of recognition memory have identified two topographically distinct ERP components, the FN400 *old/new effect* and the late posterior component (LPC) *old/new effect*, commonly associated with *familiarity* and *recollection*, respectively. Here we used a task-switching paradigm to examine the extent to which adoption of a retrieval task-set influences FN400 and LPC old/new effects, in light of the presumption that *recollection*, as a control process, relies on the adoption of a retrieval task-set, but that *familiarity*-based retrieval does not. Behavioral accuracy indicated that source memory (experiment 2), but not item recognition (experiment 1), improved with task-set adoption. ERP data demonstrated a larger LPC on stay trials when a task-set had been adopted even with a simple recognition memory judgment. We conclude that adopting a retrieval task-set impacts *recollection* memory but not *familiarity*. These data indicate that attentional state immediately prior to retrieval can influence objective measures of *recollection* memory.

Introduction

It is well established that attention is necessary for the effective encoding of new declarative information in memory. Studies of divided attention at encoding demonstrate that additional cognitive demands reduce performance on explicit tests of memory (Baddeley et al., 1984; Kellogg et al., 1982). Although dividing attention at retrieval is less disruptive, it is becoming more apparent that attention can modulate certain aspects of retrieved memories, including efficiency, accuracy, and quality (Duzel et al., 1999; Herron and Wilding, 2004, 2006; Morcom and Rugg, 2002; Wheeler et al., 2006) and that preparation to remember specific information may make memory search and recovery more efficient (Dobbins and Han, 2006). Tulving (1983) initially proposed that prior to an episodic memory retrieval attempt, subjects may adopt a cognitive set or 'retrieval mode' to ensure that stimuli are treated as episodic retrieval cues. The adoption of a retrieval mode appears to play an important role in controlled memory retrieval. Studies using functional magnetic resonance imaging (fMRI) have shown that maintenance of retrieval mode is associated with increased activation in right prefrontal cortex (Buckner, 2003; Duzel et al., 1999; Grady et al., 2001; Lepage et al., 2000; Nyberg et al., 1995; Velanova et al., 2003). Further, medial temporal lobe structures demonstrate "match enhancement" activity when stimulus repetitions are consistent with retrieval goal states (Duncan et al., 2009; Hannula and Ranganath, 2008; Miller and Desimone, 1994), which may reflect the medial temporal lobe's role in retrieval mode. Studies using event-related potentials (ERPs) have been particularly important in our current understanding of the dynamics of retrieval mode (Duzel et al., 1999; Herron and Wilding, 2004, 2006; Morcom and Rugg, 2002), given their excellent temporal resolution. These studies have identified diverging ERPs associated with preparation to perform different retrieval tasks. In particular, ERPs associated with preparation to make an episodic memory judgment are more positive-going compared with those associated with preparation to make a semantic memory judgment. This divergence in task-related ERPs prior to retrieval is typically found in anterior (frontal) electrodes, and is proposed to reflect the adoption of a retrieval mode (Duzel et al., 1999; Herron and Wilding, 2004, 2006; Morcom and Rugg, 2002).

Several ERP studies of retrieval preparation have used a task-switching paradigm to demonstrate that the adoption of a retrieval mode may not be instantiated prior to all episodic retrieval attempts (Herron and Wilding, 2006; Morcom and Rugg, 2002) but instead may emerge with at least one previous retrieval attempt. Morcom and Rugg (2002) showed that ERPs related to the preparation to perform episodic and semantic retrieval tasks diverged from one another only when subjects performed the same task on the previous trial (stay) but not when they switched from the previous task (switch),

---

[*] Corresponding author. University of Pittsburgh, 615 LRDC, 3939 O'Hara St., Pittsburgh PA 15260, USA.
E-mail address: krw37@pitt.edu (K.A. Wilckens).

1053-8119/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.neuroimage.2010.12.059

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

reflecting a more transient adoption of a retrieval task-set. Behaviorally, they showed an increase in response time with switching (switch > stay > stay + 1) but no switch costs in accuracy. Given that accuracy did not decrease on switch trials when ERPs did not reflect adoption of a retrieval task-set, these data suggest that it is not necessary to adopt a retrieval task-set to successfully make a simple old/new recognition judgment. Herron and Wilding (2006) replicated the above ERP findings, but using a source memory judgment, observed a significant linear increase in accuracy as a function of transition (switch < stay < stay + 1) suggesting that source memory accuracy improves after the adoption of a retrieval task-set. These behavioral results suggest that preparation constraining the memory search space may be more important for recovery of details rather than item memory components.

Other ERP studies of recognition memory examining the retrieval attempt have identified two distinct components associated with retrieval success, or 'old/new' effects. The FN400 old/new effect is characterized by more positive-going ERPs elicited by correctly identified studied items (hits) compared with correctly rejected unstudied items (correct rejections) in midfrontal electrodes approximately 300–500 ms after stimulus onset. The late posterior component (LPC) old/new effect is characterized by more positive-going ERPs elicited by hits compared with correct rejections (CRs) in left posterior superior electrodes approximately 500–700 ms after stimulus onset. Consistent with most dual process models of recognition memory, the FN400 old/new effect is often considered to be associated with *familiarity* or a sense of prior experience, or global similarity, whereas the LPC old/new effect has been found to be sensitive to detailed remembering, or *recollection* (Curran, 2000; Curran and Cleary, 2003; Curran et al., 2006; Curran and Dien, 2003; Curran and Hancock, 2007; Mecklinger, 2000; Nessler et al., 2001; Paller et al., 2007; Rugg and Curran, 2007; Rugg et al., 1998; Vilberg et al., 2006; Wolk et al., 2006; Woodruff et al., 2006). As opposed to the FN400, encoding manipulations appear to modulate the LPC (Curran, 2004; Norman et al., 2008; Rugg et al., 1998; Ullsperger et al., 2000). Yet, it remains unclear whether these retrieval success effects are more robust with adoption of a retrieval mode (Konishi et al., 2000) or a retrieval task-set, and whether recollection and familiarity components of retrieval success are differentially impacted by the adoption of a task-set immediately prior to the retrieval attempt.

Conceivably, adoption of a task-set may help guide the retrieval process such that the memory search is more efficiently constrained prior to retrieval. Given that previous studies have shown that the LPC, but not the FN400, is increased with the amount of information recollected (Vilberg et al., 2006), LPC retrieval modulation would suggest that changes in attention at retrieval may influence the amount of information recollected or the likelihood of recollection. Further, given that previous studies of the LPC have examined its modulation with manipulations primarily implemented at encoding (i.e. depth of processing), (Rugg et al., 1998) it is unclear whether this old/new effect is influenced by the stored representation of the memory, or also by the efficient recovery of details at retrieval. Task-switching associated modulations in the LPC would broadly suggest that the LPC old/new effect and retrieval success are impacted by preparation constraining the retrieval search to facilitate recollection of details. Broadly, this finding would be consistent with the idea that preparation to remember facilitates the memory search (Buckner, 2003; Dobbins and Han, 2006; Wheeler et al., 2006).

In two experiments we investigated the influence of episodic memory-specific task-set adoption on recollection memory. We investigated whether preparation to retrieve a memory differentially impacts the FN400 and LPC old/new effects associated with familiarity and recollection, respectively, and whether preparation influences memory accuracy in terms of simple recognition memory and detailed source memory. We used a retrieval task-switching paradigm, similar to those described above (Herron and Wilding, 2006; Morcom and Rugg, 2002), in which the retrieval task (episodic or semantic) either changed from the previous trial (switch) or stayed the same (stay). For purposes of clarity, we define retrieval mode as a tonic state that is maintained across a sequence of episodic memory judgments (Duzel et al., 1999; Nyberg et al., 1995; Velanova et al., 2003), and distinguish this from a retrieval task-set, which we define as an episodic memory-specific task-set that may alter on a trial-by-trial basis. Thus, the present study focused on retrieval task-set adoption.

We predicted that, due to the controlled processing nature of recollection (Hay and Jacoby, 1999; Jacoby, 1991, 1996; Jennings and Jacoby, 1993; Kelley and Jacoby, 2000), the LPC would be more robust on stay trials when subjects have adopted a retrieval task-set. In contrast, we predicted that the FN400 would be inert to task-switching, given the more automatic nature of processing in support of familiarity. This hypothesis is based on dual process models of recognition memory which posit that recollection, which often influences the LPC, is thought to be a more controlled process, whereas familiarity, often marked by the FN400, is thought to be more automatic (Curran, 2000; Jennings and Jacoby, 1993). We posit that the controlled processing involved in preparation prior to retrieval may help guide the retrieval process such that the memory search is more efficiently constrained prior to retrieval (Jacoby et al., 1999). This predicted outcome would suggest that subjects rely more on recollection to make recognition memory judgments when they have adopted a retrieval task-set, and that recollection, as a control process, is facilitated by preparation prior to retrieval. In a second experiment, we specifically addressed the question of whether episodic details are more likely to be retrieved with preparation. We predicted that item memory accuracy, measured in experiment 1, would be uninfluenced by task-set adoption, whereas source memory accuracy, measured in experiment 2, would improve with task-set adoption.

Experiment 1

Materials and methods

Subjects

Nineteen subjects (ages 18–30, mean 24.47) participated in the experiment. Subjects were paid at a rate of $10/h, and provided informed consent as required by the Institutional Review Board of University of Pittsburgh. One subject was excluded from all analyses because the ERP data failed to contribute ten or more artifact-free trials to the conditions of interest, and another because the subject fell asleep during the experiment. One subject only completed six of the eight study-test blocks due to technical malfunction, but the data from the six blocks were retained. Nine of the remaining seventeen subjects were female (ages 18–30, mean 22.41).

Materials

Stimuli consisted of 480 color pictures of common objects (nouns) divided into 8 lists of 60 and balanced for living versus non-living status based on a survey that was given to 15 subjects who did not participate in the experiment. The entire list consisted of ~40% living objects (194/480) and ~60% (286/480) non-living objects. Pictures were taken from multiple picture databases (The PASCAL Object Recognition Database Collection: http://pascallin.ecs.soton.ac.uk/challenges/VOC/databases.html, google images, mac images, and the Tarr Lab at Brown: http://www.tarrlab.org). Picture stimuli were modified in Photoshop such that all of the pictures consisted of a single object on a white background (Fig. 1). Assignment to condition and order of presentation of the pictures was randomized for each subject. The stimuli were presented at the center of a 16 in. screen monitor with a white background 48 in. from the subject. Pictures subtended a maximum visual angle of 11.1° vertical and 11.9° horizontal.

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

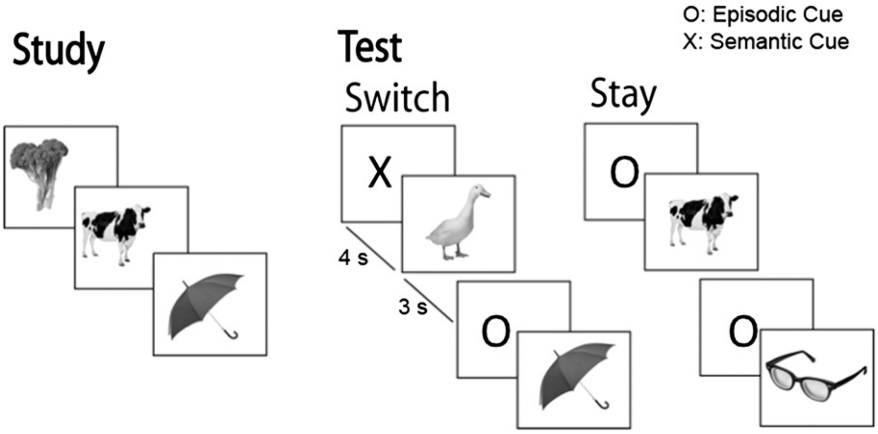


Fig. 1. Schematic of trial types during study and test sessions. "O" and "X" cues denote instruction to perform the episodic and semantic tasks, respectively. Cue phase duration is shown following cue onset. Retrieval phase duration is shown following picture onset. Examples of switch and stay trials are shown.

Experimental paradigm

The experiment alternated between study and test sessions for each of 8 blocks. In each of the 8 study sessions, 30 pictures were presented for 500 ms each. Encoding took place in the context of a size judgment task ("Is the item pictured smaller or larger than a shoebox?"). Subjects were trained on the study and test sessions prior to participation in the experiment proper. Given the prior training, subjects were aware their memory would be tested during the study session, thus encoding can be considered intentional. The study task was self-paced with a maximum of 3 s to respond. At the end of each study phase subjects took a 30 second break which was terminated by a 5 second "get ready" sign to indicate that the test portion was about to begin. In the test phase, subjects performed a cued retrieval task similar to those described in Morcom and Rugg (2002) and Phillips et al. (2009) (Fig. 1). Each test phase contained the same 30 pictures presented in the preceding study phase along with 30 new pictures. No pictures were repeated across the 8 blocks. Each picture was preceded by an instructional task cue ("O" or "X") corresponding to the episodic or semantic task, respectively. The episodic task cue directed subjects to indicate whether the subsequent object pictured was on the study list (old) or not (new). The semantic task cue directed subjects to indicate whether the object pictured was living or non-living. The instructional cue either changed from that of the previous trial (switch), was the same as the previous trial (stay), or was the same as the previous two trials (stay + 1). The instructional task cue was presented for 500 ms, followed by fixation for 4000 ms. The test picture was presented for 3000 ms, followed by a blank screen for an additional 500 ms to signal the end of the trial.

Subjects used the middle and index finger of both hands to respond, with response-to-hand mappings counterbalanced across subjects. Subjects always used the same hand for living and non-living responses, and the opposite hand for old and new responses. Subjects were trained on the experimental task prior to testing.

ERP data acquisition

The ERP procedure was similar to that of Ally et al. (2009). An elasticized Active Two electrode cap (Behavioral Brain Sciences Center, Birmingham, UK) was fitted to subjects with a full array of 128 Ag-AgCl Biosemi "active" electrodes (Amsterdam, the Netherlands). Electrodes were connected to the cap in a pre-configured montage, which places each electrode in equidistant concentric circles from 10 to 20 position Cz. As active electrodes are amplified through the electrode at the source, they do not require abrading of the skin to lower impedance levels. Additional electrodes were placed on each mastoid process, as well as below and on the outer canthus of the eyes to record vertical and horizontal electrooculogram (EOG). EEG and EOG activities were digitized at a sampling rate of 512 Hz with a low-pass filter of 0–100 Hz. A common average reference and digital filter (0.03–30 Hz within the preparatory phase, and 0.1–30 Hz within the retrieval phase) was applied to the continuous data using Brain Electrical Source Analysis (BESA) software (MEGIS software GmbH, Graefelfing, Germany).

For analyses within the preparatory phase, ERPs were formed off-line by averaging 1800 ms of digitized data time-locked to the task cue with 200 ms of pre-stimulus data serving as baseline. Likewise, for the retrieval phase, ERPs were time-locked to test probe (picture) presentation and 1200 ms of digitized data were averaged with a 200 ms pre-stimulus baseline. Eye-blinks were corrected using the BESA ocular artifact correction algorithm. Only artifact-free or blink-corrected epochs were averaged. Epochs were defined as artifacts if baseline drift exceeded ± 100 μv.

ERP data analysis

For analyses within the preparatory phase, we calculated mean amplitudes time-locked to the instructional task cue for episodic and semantic cues for each of the transition conditions (switch, stay, and stay + 1). Mean amplitudes for ERPs following the episodic and semantic task cues were calculated for one time interval (800–1500 ms) to examine ERPs related to episodic memory-specific retrieval task-set. This interval was chosen based on previous research (Morcom and Rugg, 2002) and based on visual inspection of the grand average waveforms. For analyses within the retrieval phase, mean amplitudes time-locked to the test probe onset were calculated for episodic hits and CRs in the switch and stay conditions (collapsed across stay and stay + 1) for two different time intervals (300–500 ms, and 500–700 ms) to examine old/new effects reflected by the FN400 and the LPC, respectively. Mean amplitudes were averaged across groups of electrodes to form three "central superior" regions of interest for the preparatory phase (Fig. 2): Anterior-central (AC): C11, C12, C13, C20, C21, C22, C24, C25, and C26; Midcentral (CC): A1, A2, B1, C1, D1, and D15; and Posterior-central (PC): A5, A18, A19, A20, A21, A31, and A32, and four "lateral superior" regions of interest for the retrieval phase (Fig. 2): Left anterior superior (*LAS*): D3, D4, D11, D12, and D13; Left posterior superior (*LPS*): A6, A7, D17, D27, and D28; Right anterior superior (*RAS*): B30, B31, B32, C3, and C4; Right posterior superior (*RPS*): B3, B4, B17, B18, and B19.

Experiment 1

Results

Behavioral analyses

The behavioral data indicated that retrieval task-switching influenced recognition performance in terms of response time, but

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

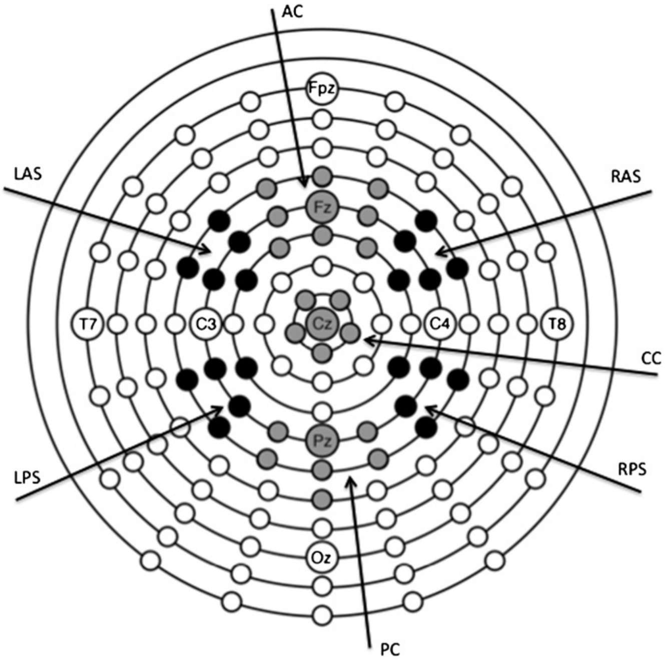


Fig. 2. Biosemi Active-Two 128-electrode layout with the 3 central superior (gray) and 4 lateral superior (black) regions of interest.

not accuracy. Mean response times (RT) in milliseconds (ms) for episodic hits, and semantic correct responses separated by transition type (switch, stay, and stay + 1), are shown in Table 1. A repeated measures ANOVA on RTs for hits in the episodic condition revealed a main effect of transition (switch, stay, stay + 1), $F(2,32)=32.363$, $p<0.001$. Post-hoc least squares difference (LSD) t-tests revealed significantly slower RTs for switch compared with stay, $t(16)=6.886$, $p<0.001$ and stay + 1 trials, $t(16)=6.565$, $p<0.001$. RTs in stay and stay + 1 conditions were marginally different from each other $t(16)=1.888$, $p=0.077$, reflecting that subjects were slower when they switched retrieval tasks compared to when they performed the same task on the previous trial (stay) and previous two trials (stay + 1). The same main effect of transition was found for correct responses in the semantic task, $F(2,32)=15.686$, $p<0.001$. Similarly, RTs in stay and stay + 1 conditions were significantly faster than those in the switch condition, $t(16)=5.741$, $p<0.001$ for stay, $t(16)=4.782$, $p<0.001$ for stay + 1, and RTs in the stay + 1 condition were marginally faster than those in the stay condition, $t(16)=1.992$, $p=0.064$. Consistent with previous behavioral findings (Morcom and Rugg, 2002), there was no main effect of transition for corrected accuracy (hits − false alarms), $F(2,32)=1.057$, $p=0.359$, reflecting no accuracy switch costs. Overall, based on the assumption that a retrieval task-set is not adopted unless the same task has been performed on the previous trial (stay) (Morcom and Rugg, 2002), these behavioral data are consistent with the view that it is not necessary to adopt a retrieval task-set in order to make an accurate item recognition memory judgment (Table 2).

ERP analyses

For all analyses, only effects of task cue, study status, and transition are reported here.

Table 1
Response times for the episodic and semantic tasks on switch, stay, and stay + 1 trials (standard error in parentheses) for experiment 1.

	Episodic	Semantic
Switch	1244.20 (72.42)	1190.35 (62.67)
Stay	1119.00 (60.21)	1106.20 (55.60)
Stay + 1	1081.09 (60.83)	1047.70 (59.08)

Table 2
Hit, false alarm, and correct rejection rates and corrected accuracy (hit—false alarm) for switch, stay, and stay + 1 (standard error in parentheses) for experiment 1.

	Hit	False alarm	Correct rejection	Corrected accuracy
Switch	.9226 (.0145)	.0672 (.0166)	.9327 (.0166)	.8553 (.0200)
Stay	.9220 (.0162)	.0777 (.0105)	.9223 (.0105)	.8445 (.0177)
Stay + 1	.9405 (.0146)	.0641 (.0213)	.9359 (.0213)	.8764 (.0267)

Preparatory phase. We first aimed to identify evidence of retrieval task-set adoption specific to episodic memory, consistent with previous findings (Herron and Wilding, 2006; Morcom and Rugg, 2002). ERPs time-locked to episodic and semantic preparatory task cues were separated according to transition type (switch, stay, stay + 1) as in Herron and Wilding (2006) and Morcom and Rugg (2002). Data from 3 subjects were excluded for analyses within the preparatory phase because their data failed to contribute more than 15 artifact-free trials in at least one of the conditions of interest. The average number of trials contributing to the preparatory phase analyses for each subject, for each condition were as follows (minimum and maximum in parentheses): Episodic switch: 100.71 (70, 133); Episodic stay: 54.29 (32, 69); Episodic stay + 1: 28.86 (19, 43); Semantic switch: 104.07 (69, 136); Semantic stay: 50.93 (33, 69); Semantic stay + 1: 25.14 (17, 35).

Preparatory phase (800–1500 ms). The first ERP analyses were aimed at identifying activity associated with episodic memory-specific retrieval task-set adoption within the preparatory phase. Given the previous findings of Herron and Wilding (2004, 2006) and Morcom and Rugg (2002), we expected that this effect would be reflected by a significant main effect of transition only for the episodic task cue in anterior electrodes beginning around 800 ms following task cue onset. Visual inspection of the data (Fig. 3) indicated that anterior-central ERPs evoked by the episodic task cue were more negative-going than those evoked by the semantic task cue in the stay condition. This effect, which persisted from approximately 800 ms until the end of the recording epoch in the stay condition, was not evident on switch trials (Fig. 3A). A 3 × 2 × 3 axis (anterior-central/midcentral/posterior-central) × task cue (episodic/semantic) × transition (switch/stay/stay + 1) repeated measures ANOVA revealed a significant axis × task cue × transition interaction, $F(4,52)=2.638$, $p<0.05$ as well as a significant axis × task cue × transition quadratic trend, $F(1,13)=6.146$, $p<0.05$, reflecting that the quadratic trend in transition was reliable only in anterior-central electrodes for episodic task cues. Subsequent analyses restricted to episodic and semantic task cues separately within anterior-central sites revealed a significant main effect of transition, $F(2,26)=5.508$, $p=0.01$, and a significant quadratic trend for episodic cues only, $F(1,13)=17.75$, $p=0.001$, F's < 1 for semantic cues, reflecting that the main effect of transition in which ERPs in the stay condition are more negative-going than those in the switch and stay + 1 conditions was reliable for episodic cues (Fig. 3B left panel), but not for semantic cues (Fig. 3B right panel). Paired samples t-tests also revealed that ERPs elicited by the episodic task cues were significantly more negative-going than those elicited by semantic cues only in the stay condition, $t(13)=2.431$, $p<0.05$. This was not the case for the switch condition, $t(13)=.435$, $p=0.671$, or the stay + 1 condition, $t(13)=.770$, $p=0.455$. That this relative negativity for episodic cues is not reliable on stay + 1 trials is consistent with the view that these effects reflect the initial adoption of a retrieval task-set on stay trials, not the maintenance of the task-set (Herron and Wilding, 2004, 2006; Morcom and Rugg, 2002).

It should be noted that in previous studies of retrieval mode (Herron and Wilding, 2006; Morcom and Rugg, 2002), ERPs elicited by episodic cues in the stay condition were more *positive*-going than other conditions, whereas, those reported here are more negative-going. This discrepancy may be due to differences in the reference

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

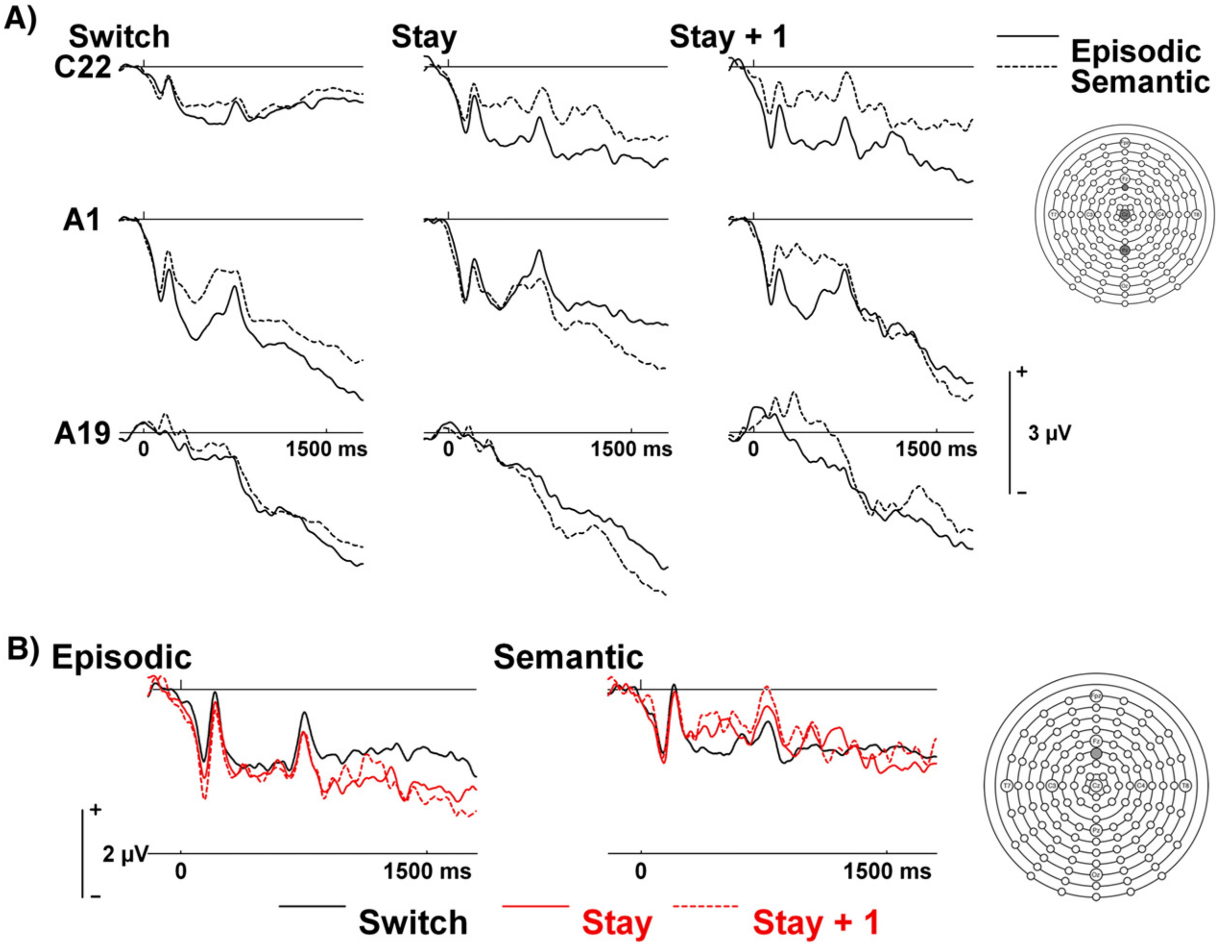


Fig. 3. (A) Grand average ERPs elicited by episodic (solid) and semantic (dotted) cues separated by switch, stay, and stay + 1 conditions at representative anterior, mid, and posterior central electrode sites (location on Biosemi Active-Two 128-electrode layout shown on the right). ERPs elicited by episodic and semantic cues diverged more in the stay condition compared with switch in anterior-central electrodes (upper panel) from 800 to 1500 ms. (B) Grand average ERPs elicited by switch (black) stay (solid red) and stay + 1 (dotted red) for episodic (left) and semantic (right) task cues at anterior-central electrode C22 (location on Biosemi Active-Two 128-electrode layout shown on the right). ERPs associated with episodic cues in the stay condition were more negative-going than those in the switch condition. This was not the case for semantic cues. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

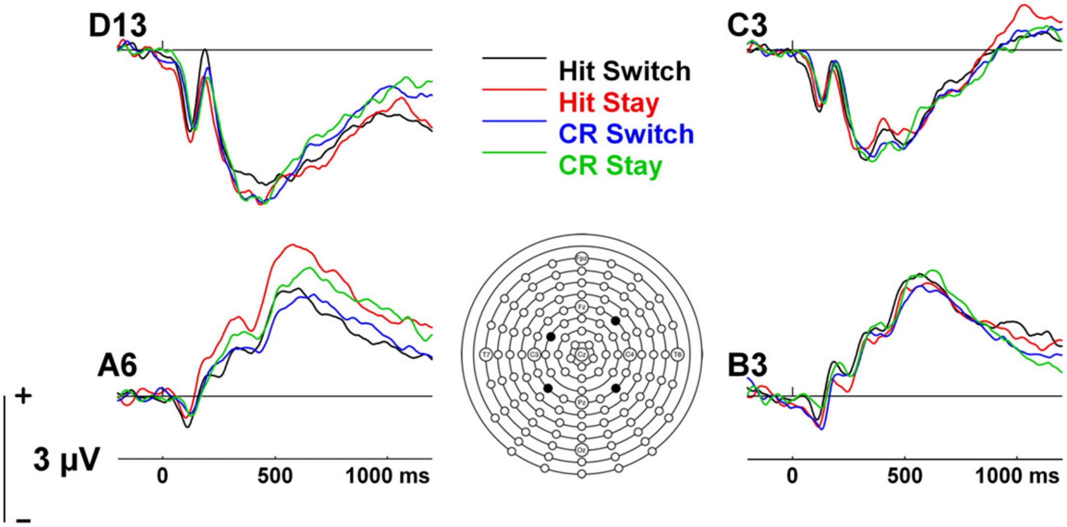


Fig. 4. Grand average ERPs elicited by hits and correct rejections in switch and stay conditions in representative electrodes for each of the four lateral superior regions of interest: LAS, LPS, RAS, and RPS. Old/new effects are larger in the stay condition in LPS electrode A6. Electrode locations on Biosemi Active-Two 128-electrode layout shown in the middle panel.

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

electrodes between these studies. Here we used a global vertex reference point as opposed to a mastoid reference.

Retrieval phase. Our primary aim was to determine whether FN400 and LPC old/new effects were differentially modulated by retrieval task-set adoption. To obtain sufficient power, we collapsed across stay and stay + 1 conditions for all retrieval phase analyses. ERPs were time-locked to test probe (picture) onset for all retrieval phase analyses. ERPs associated with hits and CRs were separated according to transition type. The mean number of contributing trials for each condition were as follows (minimum and maximum in parentheses): Hit switch: 48.24 (33, 65); Hit stay: 38.88 (31, 51); CR Switch: 49.00 (28, 69); and CR Stay: 37.82 (25, 52).

Visual inspection of the data suggested that old/new effects were largest in anterior superior electrodes between 300 and 500 ms, and posterior superior electrodes between 500 and 700 ms after memory probe onset. Fig. 4 displays grand average ERP wave-forms for hits and CRs in switch and stay conditions in representative electrodes from each of the four superior regions of interest.

FN400 (300–500 ms). To test the extent to which the FN400 old/new effect is modulated by task-switching, an omnibus 2 × 2 × 2 × 2 (Left/Right × Anterior/Posterior × Study Status × Transition) repeated measures ANOVA was conducted on ERPs elicited by hits and CRs in each transition condition within lateral superior electrode groups. This analysis revealed a significant main effect of study status, $F(1,16) = 15.658$, $p = 0.001$ in which hits were more positive-going than CRs for both switch and stay trials. Subsequent analyses restricted to anterior sites between 300 and 500 ms revealed a significant main effect of study status, $F(1,16) = 8.514$, $p = 0.01$ and no interactions. Similarly, this analysis restricted to posterior electrodes revealed a significant main effect of study status, $F(1,16) = 10.486$, $p = 0.005$, and no interactions. These results reflect reliable FN400 old/new effects not modulated by switching across lateral superior electrodes bilaterally.

LPC (500–700 ms). The next analyses were aimed at identifying whether the LPC old/new effect is reliably modulated by task-switching. This ERP component is typically most robust in left posterior superior (LPS) sites approximately 500–700 ms following test probe onset (Curran, 2004; Rugg and Curran, 2007). Analyses restricted to LPS sites, within the 500–700 ms interval revealed significant main effects of study status, $F(1,16) = 5.496$, $p < 0.05$, and transition, $F(1,16) = 8.225$, $p < 0.025$, and a significant study status × transition interaction, reflecting a larger left parietal old/new effect in the stay condition relative to the switch condition, $F(1,16) = 4.771$, $p < 0.05$. There was a main effect of study status in RPS sites, $F(1,16) = 7.269$, $p < .05$, but this effect was not modulated by transition, $F(1,16) = 0.067$, $p = 0.799$. Follow-up paired t-tests in LPS sites revealed that hits were significantly more positive-going than CRs in the stay condition, $t(16) = 3.687$, $p < 0.005$, but not in the switch condition, $t(16) = 0.795$, $p = 0.437$. In RPS sites, old/new effects did not reach significance in both the switch, $t(16) = 1.972$, and stay conditions $t(16) = 1.783$, consistent with previous studies showing maximal old/new effects on the left (Ally et al., 2008, 2009; Olichney et al., 2000; Rugg and Curran, 2007; Vilberg et al., 2006; Wolk et al., 2006). This interaction in which old/new effects were larger in the stay condition relative to the switch condition in LPS electrodes affirms our prediction that the LPC old/new effect is more robust on stay trials than on switch trials. This effect is illustrated in Fig. 4: In the representative LPS electrode, A6, there were larger differences between ERPs elicited by hits and CRs in the stay condition relative to the switch condition. This effect was also evident in the scalp topographies. Old/new effects were maximal at midfrontal sites in the switch condition, and left posterior sites for the stay condition (Fig. 5). Thus these scalp topographies support our prediction that late old/new effects typically associated with recollection are reliable when subjects are more likely to have adopted a retrieval task-set.

Experiment 2

Introduction

Experiment 2 was designed to test whether source memory accuracy would benefit from task-set adoption. Given that recognition accuracy was not influenced by task-switching in experiment 1, but the ERP data demonstrated an intact LPC only in the stay condition, we expected that source memory accuracy, a putative marker of recollection memory would be influenced by task-switching. We tested this hypothesis in experiment 2.

Materials and methods

Subjects

Twenty-four subjects (ages 18–29, mean 19.92) participated in experiment 2. Subjects were recruited from the undergraduate

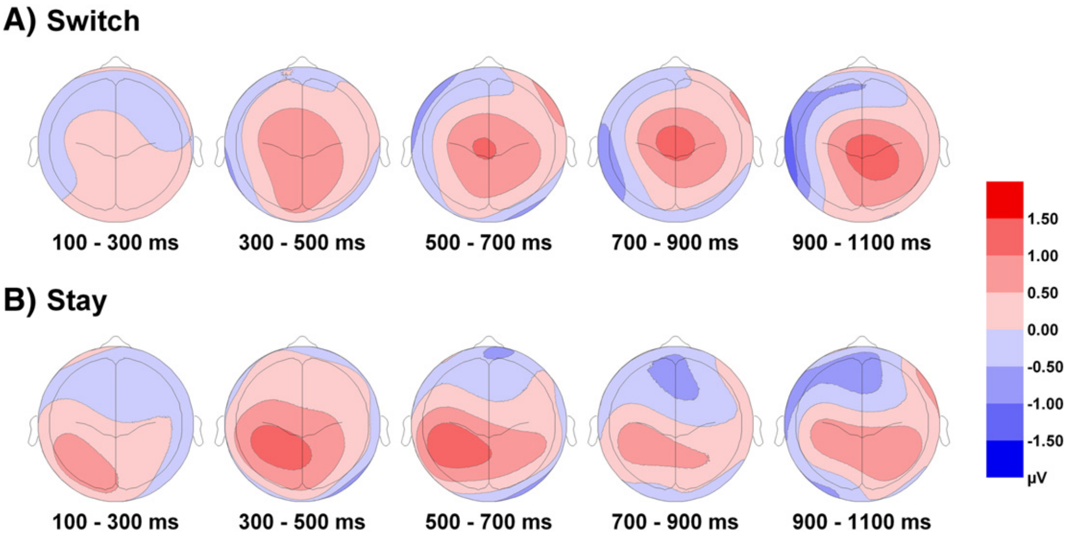


Fig. 5. Scalp topographies reflecting old/new effects for (A) switch and (B) stay conditions (hit > CR). A) Old/new effects in the switch condition are maximal at mid anterior superior sites. B) Old/new effects in the stay condition are maximal at LPS sites. These scalp topographies reflect a larger LPC old/new effect in the stay condition compared with the switch condition.

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

psychology subject pool at the University of Pittsburgh and given research credit for their participation. Subjects provided informed consent as required by the Institutional Review Board of University of Pittsburgh. Data from two subjects were excluded from all analyses due to a technical error and early termination of the experiment by the participant. Fifteen of the remaining twenty-two subjects were female (ages 18–29, mean 20.09).

Procedure

The procedure for experiment 2 was similar to that of experiment 1. The critical difference was that experiment 2 tested source memory accuracy. The experiment alternated between study and test sessions for each of 4 blocks. In each of the 4 study sessions, 30 pictures were presented for 500 ms each. Additionally, in experiment 2, the study session included two blocks of study trials. In one block, subjects performed a pleasantness judgment in which they indicated whether the object pictured was pleasant or unpleasant. It was emphasized that there was no veridical response to this portion of the experiment and that subjects should base their judgment on their opinion. In another block of study trials, subjects performed a moving/non-moving task. For this task, subjects indicated whether the object pictured would move on its own volition in real life. Study block order was random for each study-test cycle for each subject. At the beginning of each study block, subjects were given instructions as to which study task to perform (pleasantness or moving/non-moving). Throughout the study session, pictures appeared on the left side of the screen or the right side of the screen. Subjects were told to attend to the side of the screen on which the pictures appeared because it would be relevant for the later test portion. Subjects trained on the study and test sessions prior to participation in the experiment proper. Given the prior training, subjects were aware their memory would be tested during the study session, thus encoding can again be considered intentional. The study task was self-paced with a maximum of 3 s to respond. At the end of each study session subjects were reminded of the test instructions prior to the start of the test session. In the test session, the same 30 pictures presented in the preceding study session were presented along with 30 new pictures. No pictures were repeated across the 4 blocks. Prior to the presentation of each picture, subjects were cued to perform either one of two episodic retrieval tasks or a semantic task. One episodic task instructed subjects to retrieve the location of the picture at study (left or right). Subjects were instructed to indicate whether the word appeared on the left side of the screen or the right side of the screen by making a button press with their index finger to indicate "left", their middle finger to indicate "right" and their ring finger to indicate that the word was new (not presented at study). This retrieval task will be referred to as the location task. The other episodic retrieval task instructed subjects to retrieve which encoding task they performed on the probe word. Subjects were instructed to indicate which study task they performed by using their index finger to indicate "pleasantness task", their middle finger to indicate the moving/non-moving task, and their ring finger to indicate that the word was new. This retrieval task will be referred to as the operation task, consistent with the terminology used by Herron and Wilding (2004). The semantic task was the same as that of experiment 1. Subjects judged whether the object pictured was living or non-living. Subjects indicated the object was living with their index finger, non-living with their middle finger, and used their ring finger to indicate if they were unsure of the living/non-living status. The instructional cue either changed from that of the previous trial (switch), was the same as the previous trial (stay), or was the same as the previous two trials (stay + 1). The instructional task cue was presented for 500 ms, followed by fixation for 4000 ms. The test picture was presented for 3000 ms, followed by a blank screen for an additional 500 ms to signal the end of the trial.

Results

Behavioral results indicated that retrieval task-switching influenced source memory performance in terms of response time as well as accuracy. Mean response times for correct source judgments for both location and operation tasks separated by transition type (switch, stay, stay + 1) are shown in Table 3. A main effect of transition, $F(2,42) = 5.704$, $p < 0.01$, revealed that response times were significantly slower in the switch condition compared with stay, $t(21) = 2.439$, $p < 0.05$, and stay + 1, $t(21) = 2.98$, $p < 0.01$. Mean correct source judgments for both the location and operation tasks separated by transition type (switch, stay, and stay + 1), are shown in Table 4. A task cue (location/operation) × transition (switch/stay/stay + 1) repeated measures ANOVA revealed a main effect of task cue, $F(1,21) = 19.11$, $p < 0.001$, reflecting that source memory performance was greater following location cues compared with operations cues. Critically, this analysis also revealed a significant main effect of transition, $F(2,42) = 3.894$, $p < 0.05$, with no task cue × transition interaction, $F(2,42) = 1.794$, $p = 0.179$. A follow-up paired samples t-test collapsed across source memory tasks and stay and stay + 1 conditions, revealed that source accuracy in the switch condition was significantly poorer than source accuracy in the stay condition, $t(21) = 3.358$, $p < 0.005$. This result demonstrates that source memory accuracy is influenced by task-switching and is consistent with the view that a subject's ability to engage in recollection is influenced by task-set adoption.

Discussion

Here we showed evidence that preparation influences the LPC old/new effect, an ERP correlate of recollection memory. The LPC old/new effect was influenced by the successful adoption of a retrieval task-set whereas, the FN400 old/new effect, an ERP correlate of familiarity, was not. To support these ERP results, behavioral data showed that while item recognition memory accuracy was not influenced by task-switching in experiment 1, source memory performance in experiment 2 was significantly improved with task-set adoption. These results support the view that preparation is important for constraining the retrieval search space to access details (Buckner, 2003; Dobbins and Han, 2006; Jacoby et al., 1999, 2005).

We examined the influence of retrieval task-set adoption on ERP correlates of retrieval success associated with recollection and familiarity. Behaviorally, response times but not item recognition accuracy were influenced by task-switching, supporting the view that successful retrieval task-set adoption is not necessary to successfully make a simple recognition memory decision (Morcom and Rugg, 2002) and suggesting that subjects may rely more on familiarity when a task-set has not been adopted. Consistent with this view, behavioral results from experiment 2 demonstrated significant switch-costs in accuracy when a source memory judgment was required, reflecting that recollection or source memory, but not item memory is influenced by task-set adoption. These behavioral findings are consistent with Herron and Wilding (2006). In terms of the ERP data, within the preparatory phase we replicated previous ERP findings (Herron and Wilding, 2004, 2006; Morcom and Rugg, 2002) showing that ERPs elicited by the preparation to perform the two retrieval tasks diverged on stay trials but not on switch trials,

Table 3
Response times for correct source judgments for location and operation tasks on switch, stay and stay + 1 trials (standard error in parentheses) for experiment 2.

	Location	Operation	Mean
Switch	1279.21 (53.22)	1451.31 (77.46)	1365.26 (62.06)
Stay	1205.01 (52.22)	1404.87 (56.31)	1304.94 (51.84)
Stay + 1	1186.25 (50.94)	1410.17 (67.58)	1298.21 (56.30)

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

Table 4
Source accuracy percent correct for the location and operation tasks, and the mean collapsed across the two tasks, on switch, stay, and stay + 1 trials (standard error in parentheses) for experiment 2.

	Location	Operation	Mean
Switch	75.05 (14.51)	59.66 (14.17)	67.36 (10.81)
Stay	76.14 (13.66)	63.64 (13.80)	69.89 (12.07)
Stay + 1	76.61 (13.32)	68.09 (10.90)	72.35 (8.93)

reflecting the adoption of a retrieval task-set with at least one previous retrieval attempt (Fig. 3). We also replicated the finding that this effect was not reliable on stay + 1 trials. This finding is consistent with the hypothesis that these ERP effects reflect the initial adoption of a task-set on stay trials rather than the maintenance of such (Morcom and Rugg, 2002). Alternatively, if these preparatory effects reflected the maintenance of a retrieval task-set, the same divergence in ERPs related to preparation to perform the two tasks would be significant for both stay as well as stay + 1 trials.

The critical novel finding reported here is that ERPs elicited by hits within the retrieval phase were more positive-going than those elicited by CRs between 500 and 700 ms in LPS electrodes only in the stay condition, when subjects had made at least one prior retrieval attempt. Further, ERPs elicited by hits were more positive-going than CRs between 300 and 500 ms across superior electrodes for *both* switch and stay trials. These results demonstrate that the LPC old/new effect, an ERP correlate of recollection (Curran, 2000, 2004; Curran and Cleary, 2003; Curran et al., 2006; Curran and Dien, 2003; Curran and Hancock, 2007; Mecklinger, 2000; Nessler et al., 2001; Rugg and Curran, 2007; Rugg et al., 1998; Ullsperger et al., 2000; Wolk et al., 2006), is influenced by the adoption of a retrieval task-set. This result was supported with the behavioral findings of experiment 2, which demonstrated significantly greater source memory accuracy, a putative marker of recollection, on stay trials when subjects have adopted a task-set. Together these results demonstrate that preparation is important for the recovery of memory details.

One caveat worth noting is that the source memory behavioral data suggest that the influence of task-set on the recovery of associative details may depend on the content being retrieved, as exhibited by the relatively selective effect of transition on source accuracy for the operation task. Although the task × transition interaction was not significant, it is possible that the relative availability of different recollective details, or the nature of these details (e.g. location versus operation), may influence the degree to which task-switching modulates recollection. Further, it is unclear whether the more robust LPC old/new effect seen with the item recognition task of experiment 1 was a reflection of retrieval for the particular task performed at encoding (size judgment) or some other aspect of the study episode. Further, based on the results of experiment 2, it is possible that source memory judgments requiring recovery of operation information would demonstrate more robust modulation of LPC old/new effects with adoption of a task-set, while old/new effects elicited by location judgments would not be influenced by task-set. However, it is also possible in the latter case that non-criterial recollective details would be recovered in the location task to a greater extent with adoption of an appropriate task-set despite the lack of change in source accuracy, and LPC differences would not be found. As the literature has produced variable data on the influence of task-set on accuracy in similar designs (Duzel et al., 1999; Herron and Wilding, 2004, 2006; Morcom and Rugg, 2002), further work is needed to explore the relationship between the demands of task-switching and the content of episodic information that is the target of retrieval, as well as the encoding and retrieval conditions that additionally influence this relationship. Nonetheless, despite the differences between the tasks of experiment 1 and 2, the converging influence of task-switching on both ERP and behavioral measures supports the general notion of the potential influence of task-sets on recollection.

In contrast to the LPC, the FN400 old/new effect, an ERP correlate of familiarity, was not modulated by the adoption of a retrieval task-set. These data support the claim that recollection, as a control process (Hay and Jacoby, 1999; Jacoby, 1991, 1996; Jennings and Jacoby, 1993; Kelley and Jacoby, 2000) is made more available when a retrieval task-set has been adopted. Familiarity however, which is conceived of as a more automatic process, is unaffected by preparation prior to retrieval. These results are supported by the dissociation in the behavioral accuracy results of the two experiments reported here. In experiment 1, recognition memory accuracy was not influenced by task-switching, supporting the view that subjects may have made use of familiarity to make a memory judgment in the switch condition when a task-set had not yet been adopted.

The pattern of ERP results reported here is consistent with previous studies that have manipulated processing at encoding. Rugg et al. (1998) showed that the FN400 old/new effect was not modulated by depth of processing at encoding, but that the LPC old/new effect was greater for items studied through a deep encoding task compared with a shallow encoding task. Curran (2004) showed that the FN400 old/new effect was not modulated by full versus divided attention at encoding, but that the LPC old/new effect was greater with full attention at encoding, suggesting that details are more likely to be later recollected when attention is fully allocated during study. Additionally, Norman et al. (2008) manipulated interference (list strength) at encoding and also found that the FN400 was not modulated by weak versus strong interference. However, the LPC old/new effect was greater with weak interference. This finding suggests that subjects were more likely to engage in recollection when interference from other study items was minimal.

Our current findings are unique from the abovementioned results because this is the first demonstration that the LPC old/new effect, as an ERP correlate of recollection, is influenced by changes in attentional demands immediately preceding the retrieval attempt. This finding suggests that recollection is made more available when a subject has adopted a retrieval task-set or oriented attention to the appropriate mnemonic information. This is a noteworthy finding because it highlights the involvement of preparation immediately prior to a retrieval attempt, even for simple recognition memory judgments. It also highlights the controlled processing nature of recollection and the LPC old/new effect. The results of experiment 2 support this interpretation given the improved accuracy for source memory judgments with task-set adoption. Overall, this result suggests that preparation to engage in episodic memory retrieval may help to guide the retrieval process making recollection of memory details more available or accessible.

Conclusion

We conclude that preparing to engage in episodic memory retrieval influences the extent to which a recognition judgment is based on recollection memory or a more vague sense of familiarity. The ERP results demonstrate the impact of top-down control processing even on simple recognition memory judgments. These findings also raise the question of whether failure to adopt a retrieval task-set or retrieval mode may be relevant to age-related memory impairments. Given that recollection but not familiarity often declines with advanced age (Hay and Jacoby, 1999; Jennings and Jacoby, 1993), it may be that difficulties in engaging a retrieval task-set partly underlie difficulties with recollection memory in older adults.

Acknowledgments

The authors thank Haoxuan Xu, Leslie Denlinger, and Regina Cesaro for assistance with the behavioral data analysis, Ashley

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059

Abraham for assistance with stimulus collection, and Eric Signoff for assistance with ERP data collection. This project was supported by the National Institute of General Medical Sciences (T32GM081760 to K. A. W.) and the National Institute of Mental Health (MH086492 to M.E.W.) at the National Institutes of Health, and by the University of Pittsburgh Institute on Aging. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute of General Medical Sciences or the National Institutes of Health.

References

Ally, B.A., Waring, J.D., Beth, E.H., McKeever, J.D., Milberg, W.P., Budson, A.E., 2008. Aging memory for pictures: using high-density event-related potentials to understand the effect of aging on the picture superiority effect. Neuropsychologia 46, 679–689.

Ally, B.A., McKeever, J.D., Waring, J.D., Budson, A.E., 2009. Preserved frontal memorial processing for pictures in patients with mild cognitive impairment. Neuropsychologia 47, 2044–2055.

Baddeley, A., Lewis, V., Eldridge, M., Thomson, N., 1984. Attention and retrieval from long-term memory. J. Exp. Psychol. Gen. 113, 518–540.

Buckner, R.L., 2003. Functional-anatomic correlates of control processes in memory. J. Neurosci. 23, 3999–4004.

Curran, T., 2000. Brain potentials of recollection and familiarity. Mem Cognit 28, 923–938.

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

Curran, T., Cleary, A.M., 2003. Using ERPs to dissociate recollection from familiarity in picture recognition. Brain Res. Cogn. Brain Res. 15, 191–205.

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

Curran, T., Hancock, J., 2007. The FN400 indexes familiarity-based recognition of faces. Neuroimage 36, 464–471.

Curran, T., DeBuse, C., Woroch, B., Hirshman, E., 2006. Combined pharmacological and electrophysiological dissociation of familiarity and recollection. J. Neurosci. 26, 1979–1985.

Dobbins, I.G., Han, S., 2006. Cue- versus probe-dependent prefrontal cortex activity during contextual remembering. J. Cogn. Neurosci. 18, 1439–1452.

Duncan, K., Curtis, C., Davachi, L., 2009. Distinct memory signatures in the hippocampus: intentional states distinguish match and mismatch enhancement signals. J. Neurosci. 29, 131–139.

Duzel, E., Cabeza, R., Picton, T.W., Yonelinas, A.P., Scheich, H., Heinze, H.J., Tulving, E., 1999. Task-related and item-related brain processes of memory retrieval. Proc. Natl Acad. Sci. USA 96, 1794–1799.

Grady, C.L., McIntosh, A.R., Beig, S., Craik, F.I., 2001. An examination of the effects of stimulus type, encoding task, and functional connectivity on the role of right prefrontal cortex in recognition memory. Neuroimage 14, 556–571.

Hannula, D.E., Ranganath, C., 2008. Medial temporal lobe activity predicts successful relational memory binding. J. Neurosci. 28, 116–124.

Hay, J.F., Jacoby, L.L., 1999. Separating habit and recollection in young and older adults: effects of elaborative processing and distinctiveness. Psychol. Aging 14, 122–134.

Herron, J.E., Wilding, E.L., 2004. An electrophysiological dissociation of retrieval mode and retrieval orientation. Neuroimage 22, 1554–1562.

Herron, J.E., Wilding, E.L., 2006. Brain and behavioral indices of retrieval mode. Neuroimage 32, 863–870.

Jacoby, L.L., 1991. A process dissociation framework: separating automatic from intentional uses of memory. J. Mem. Lang. 30, 513–541.

Jacoby, L.L., 1996. Dissociating automatic and consciously controlled effects of study/test compatibility. J. Mem. Lang. 35, 32–52.

Jacoby, L.L., Kelley, C.M., McElree, B.D., 1999. The role of cognitive control: early selection versus late correction. In: Chaiken, S., Trope, Y. (Eds.), Dual-Process Theories in Social Psychology. Guilford, New York.

Jacoby, L.L., Shimizu, Y., Daniels, K.A., Rhodes, M.G., 2005. Modes of cognitive control in recognition and source memory: depth of retrieval. Psychon. Bull. Rev. 12, 852–857.

Jennings, J.M., Jacoby, L.L., 1993. Automatic versus intentional uses of memory: aging, attention, and control. Psychol. Aging 8, 283–293.

Kelley, C.M., Jacoby, L.L., 2000. Recollection and familiarity: process-dissociation. In: Tulving, E., Craik, F.I.M. (Eds.), The Oxford Handbook of Memory. Oxford, New York, pp. 215–228.

Kellogg, R.T., Cocklin, T., Bourne Jr., L.E., 1982. Conscious attentional demands of encoding and retrieval from long-term memory. Am. J. Psychol. 95, 183–198.

Konishi, S., Wheeler, M.E., Donaldson, D.I., Buckner, R.L., 2000. Neural correlates of episodic retrieval success. Neuroimage 12, 276–286.

Lepage, M., Ghaffar, O., Nyberg, L., Tulving, E., 2000. Prefrontal cortex and episodic memory retrieval mode. Proc. Natl Acad. Sci. USA 97, 506–511.

Mecklinger, A., 2000. Interfacing mind and brain: a neurocognitive model of recognition memory. Psychophysiology 37, 565–582.

Miller, E.K., Desimone, R., 1994. Parallel neuronal mechanisms for short-term memory. Science 263, 520–522.

Morcom, A.M., Rugg, M.D., 2002. Getting ready to remember: the neural correlates of task set during recognition memory. NeuroReport 13, 149–152.

Nessler, D., Mecklinger, A., Penney, T.B., 2001. Event related brain potentials and illusory memories: the effects of differential encoding. Brain Res. Cogn. Brain Res. 10, 283–301.

Norman, K.A., Tepe, K., Nyhus, E., Curran, T., 2008. Event-related potential correlates of interference effects on recognition memory. Psychon. Bull. Rev. 15, 36–43.

Nyberg, L., Tulving, E., Habib, R., Nilsson, L.G., Kapur, S., Houle, S., Cabeza, R., McIntosh, A.R., 1995. Functional brain maps of retrieval mode and recovery of episodic information. NeuroReport 7, 249–252.

Olichney, J.M., Van Petten, C., Paller, K.A., Salmon, D.P., Iragui, V.J., Kutas, M., 2000. Word repetition in amnesia. Electrophysiological measures of impaired and spared memory. Brain 123 (Pt 9), 1948–1963.

Paller, K.A., Voss, J.L., Boehm, S.G., 2007. Validating neural correlates of familiarity. Trends Cogn. Sci. 11, 243–250.

Phillips, J.S., Velanova, K., Wolk, D.A., Wheeler, M.E., 2009. Left posterior parietal cortex participates in both task preparation and episodic retrieval. Neuroimage 46, 1209–1221.

Rugg, M.D., Curran, T., 2007. Event-related potentials and recognition memory. Trends Cogn. Sci. 11, 251–257.

Rugg, M.D., Mark, R.E., Walla, P., Schloerscheidt, A.M., Birch, C.S., Allan, K., 1998. Dissociation of the neural correlates of implicit and explicit memory. Nature 392, 595–598.

Tulving, E., 1983. Elements of Episodic Memory. Clarendon Press, Oxford.

Ullsperger, M., Mecklinger, A., Muller, U., 2000. An electrophysiological test of directed forgetting: the role of retrieval inhibition. J. Cogn. Neurosci. 12, 924–940.

Velanova, K., Jacoby, L.L., Wheeler, M.E., McAvoy, M.P., Petersen, S.E., Buckner, R.L., 2003. Functional-anatomic correlates of sustained and transient processing components engaged during controlled retrieval. J. Neurosci. 23, 8460–8470.

Vilberg, K.L., Moosavi, R.F., Rugg, M.D., 2006. The relationship between electrophysiological correlates of recollection and amount of information retrieved. Brain Res. 1122, 161–170.

Wheeler, M.E., Shulman, G.L., Buckner, R.L., Miezin, F.M., Velanova, K., Petersen, S.E., 2006. Evidence for separate perceptual reactivation and search processes during remembering. Cereb. Cortex 16, 949–959.

Wolk, D.A., Schacter, D.L., Lygizos, M., Sen, N.M., Holcomb, P.J., Daffner, K.R., Budson, A.E., 2006. ERP correlates of recognition memory: effects of retention interval and false alarms. Brain Res. 1096, 148–162.

Woodruff, C.C., Hayama, H.R., Rugg, M.D., 2006. Electrophysiological dissociation of the neural correlates of recollection and familiarity. Brain Res. 1100, 125–135.

Please cite this article as: Wilckens, K.A., et al., Effects of task-set adoption on ERP correlates of controlled and automatic recognition memory, NeuroImage (2011), doi:10.1016/j.neuroimage.2010.12.059