Modality-match effect in false recognition: an event-related potential study

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In the Deese–Roediger–McDermott (DRM) paradigm, participants falsely recall or recognize a nonpresented word (critical lure), highly associated with previously studied words. As numerous DRM studies have found a robust false memory effect at the behavioural level, event-related potentials (ERPs) studies have searched for possible overlapping in brain electrical activity between true and false memory. Using the DRM paradigm, the present experiment manipulated the sensory modality of stimulus presentation (auditory vs. visual) in the study phase to analyse the effect of modality match between study and test on true and false recognition. Words were therefore presented either visually or auditorily at study and always visually at test. True recognition was found to be significantly higher in the modality 'match' condition (visual–visual) than in the 'mismatch' condition (auditory–visual), whereas there was no modality-match effect on false recognition of critical lures. A general, overlapping was found between ERP correlates of true and false recognition: FN400 (300–500 ms), left-parietal (400–800 ms) and late right-frontal (1000–1500 ms) old/new effects were similar for both studied words and critical lures. No sensory modality-match effect was associated with FN400 or left-parietal old/new effects. Only the late right-frontal activity was modulated by modality manipulation, with significantly more positive ERPs in the modality-match condition. Sensory modality match of stimulus presentation, therefore, dissociated true and false recognition memory only at the behavioural level but not at the ERP level. Overall, true and false recognition memories seem to share common underlying processes. *NeuroReport* 24:108–113 © 2013 Wolters Kluwer Health | Lippincott Williams & Wilkins.

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Introduction

The Deese–Roediger–McDermott (DRM) paradigm [1,2] has now become a classic procedure in the study of false memories. In this paradigm, individuals are induced to falsely recall/recognize a nonstudied critical lure word (e.g. sleep) through the previous study of a list of related words (e.g. bed, rest, awake, tired, dream, etc.). This 'memory illusion' effect has proved to be a robust phenomenon whereby the false recall/recognition rate can be as high as the true recall/recognition rate [2]. An interesting approach to exploration of the nature of this memory illusion is to search for some possible overlapping between true and false memory, assessing, for example, whether false memories are affected by the same variables that affect true memories. This experiment provides a contribution in this sense using a recognition memory task.

A large part of the recognition memory literature claims that recognition is based on two fundamental and distinct processes: familiarity and recollection [3]. Although recollection refers to a clear and detailed retrieval of the study episode, the definition of familiarity is more controversial. By and large, familiarity is identified with a more general feeling of 'already experienced' on the basis of some kind of automatic 'fluency' and without the retrieval of specific information about the study episode. Event-related potential (ERP) studies [4,5] have identified the electrophysiological correlate of familiarity in an early (300–500 ms), frontal, FN400 component, which is more positive for correctly classified old items than for correctly rejected new items. The ERP correlate of recollection is identified in a parietal effect (500–800 ms) that not only discriminates between correctly identified old/new items but is also sensitive to manipulation of the level of processing at encoding [4,6]. A third ERP correlate of recognition has also been highlighted, but mainly in false memory studies [7], and this is a late right-frontal old/new component (1000–1500 ms), usually associated with postretrieval monitoring processes.

The main aim of the current study was to explore the effects that manipulating the matching of stimulus sensory modality between study and test [visual–visual (VV) vs. auditory–visual (AV)] would have on behavioural and electrophysiological measures of both true and false recognition. Some previous work shows that this type of manipulation affects familiarity, hence the FN400 component [5]; however, to what extent familiarity and the FN400 component are influenced by perceptual information is still an open debate in the literature [4,5]. This experiment therefore aimed to shed some light on this issue, but, most of all, its purpose was to determine

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whether true and false recognition memories would be similarly affected by sensory modality-match manipulation [8]. As for the 500–800 ms parietal effect, the standard old/new effect was expected and, again, the aim was to determine whether false and true memories would present analogous ERP components. The same reasoning also applies to the old/new frontal component at the last time window (1000–1500 ms), usually associated with monitoring processes. The ERP correlates of false memories in this last time window are also particularly interesting as not only is 'monitoring' one key process in one of the main theories about the DRM memory illusion [9] but also because a recent study has highlighted the importance of monitoring strategies to lower the false memory rate [10].

Methods

Participants

One-hundred and twelve students of the University of Salamanca, all native Spanish speakers, participated in the experiment. The study was approved by the local Ethics Committee, and all participants signed a written informed consent. Participation was voluntary and not remunerated. After selection of participants with a sufficient number of artefact-free trials, 98 individuals were included in the analysis (81 women; mean age = 20.9 years, SD = 2.5), with 49 participants in each experimental group.

Stimuli

Ten DRM word lists were constructed using the free association norms for the Spanish language [11,12]. Each 10-word list was highly associated with a nonpresented critical lure. In addition to the critical lure itself, the first two strongest associated words of each list were used as nonpresented critical lures at study [13]. Each list therefore included eight associated words (e.g. darkness, stars, black, sleep, light, dream, nightmare, sky) and three nonpresented critical lures (e.g. night, day, owl). Thirty additional words were presented at test as unrelated distractors [11].

Design and procedure

The experiment was divided into a study phase and a test phase. Study-test sensory modality match (VV vs. AV) was manipulated between participants. Loudspeakers were used for the auditory presentation and a computer screen for the visual presentation of stimuli. In the study phase, 80 words were presented in blocked lists. While each word was presented, participants had 1500 ms to say whether or not it contained the letter 'o'. Participants were instructed to memorize each word read, or heard, for a subsequent memory test. They also had to carry out some simple arithmetic operations for 20 s as a filler task between lists.

In the test phase, 120 words were presented visually in a randomized order: 60 studied words, 30 critical lures and 30 unrelated distractors. Following a 1000 ms fixation cross, each word was shown for 500 ms. Two seconds later, participants made an old/new recognition decision while a yes/no sign remained on the screen.

Event-related potential recording

During the experiment, electroencephalogram was recorded continuously, at a rate of 500 Hz, from 64 Ag/AgCl electrodes mounted on an elastic cap (Electro-Cap International, Eaton, Ohio, USA), with a bandpass of 0.1–35 Hz. Interelectrode impedance was maintained below 10 kΩ. Ocular artefacts were corrected offline according to the method of Gratton *et al.* [14]. Electroencephalogram data were segmented from 300 ms before stimulus onset to 4000 ms after stimulus onset and filtered (low-pass filter at 35 Hz, 12 dB/oct). The waveforms were baseline corrected using the activity during the 300 ms before stimulus onset. For ERP analysis, the mean amplitudes were compared between conditions in three time windows (300–500, 400–800 and 1000–1500 ms). Regions of interest were the left anterior (F1, F3), left parietal (P3) and right frontal (F6), to study, respectively, the FN400, the left-parietal and the late right-frontal old/new effects [8,15].

Results

Behavioural data

An Item type (old, lure, new) × Modality-match (VV, AV) analysis of variance (ANOVA), with Item type as a repeated factor, indicated a main effect of Item type [$F(2,192) = 558.9$; $P < 0.001$] and a significant interaction [$F(2,192) = 3.2$; $P < 0.05$]. Scheffe post-hoc tests showed that true recognition (hits) was higher than both false recognition (false alarms to critical lures) and false alarms to distractors (69, 45 and 13%, respectively; $P < 0.001$). There were also significant differences between false alarms to critical and distractor items ($P < 0.001$), confirming that there was false recognition. Studied words were better remembered in the study-test modality-match (VV) condition than in the modality-mismatch (AV) condition (72 vs. 65%) [$t(96) = -2.9$; $P < 0.01$]. However, no study-test modality-match effect was found with false recognition of lure items (45% in both match and mismatch conditions), [$t(96) = 0.09$; $P = 0.925$], or with false alarms to unrelated items [$t(96) = 0.1$; $P = 0.918$].

Event-related potential data

The average ERPs were calculated for 'old-yes', 'lure-yes' and 'new-no' answers for the sensory modality match (VV) and mismatch (AV) conditions. A 3 (Item type: old, lure, new) × 2 (Modality match: VV, AV) ANOVA was carried out separately for each time window/region of interest: at 300–500 ms (F1, F3), 400–800 ms (P3) and 1000–1500 ms (F6).

As for the 300–500 ms time window, a main effect of Item type was found [$F(2,192) = 5.6$; $P < 0.01$], but neither modality-match effect [$F(1,96) = 0.1$; $P > 0.05$] nor interaction [$F(2,192) = 0.04$; $P > 0.05$] was detected. Scheffe post-hoc tests showed significant differences between old-yes and new-no ERP correlates ($P < 0.05$), as well as between lure-yes and new-no ERP correlates ($P < 0.05$). These results confirmed that there was an FN400 old/new effect for both studied words and critical lures, and that modality matching between the study and the test did not affect this early ERP component.

As for the 400–800 time window, a significant main effect of Item type was found [$F(2,192) = 9.1$; $P < 0.01$] (Fig. 1), but the modality-match effect [$F(1,96) = 0.13$; $P > 0.05$] and interaction [$F(2,192) = 0.14$; $P > 0.05$] were not significant. Scheffe post-hoc tests showed that old-yes ERP correlates were significantly more positive than new-no ERP correlates ($P < 0.01$), and that lure-yes ERP correlates were significantly more positive than new-no ERP correlates ($P < 0.05$). The left-parietal old/new effect was therefore found for both studied items and critical lures. There was no detectable difference ($P > 0.05$) between old-yes and lure-yes answers.

As for the 1000–1500 ms time window, the ANOVA indicated the main effects of Item type [$F(2,192) = 22.3$; $P < 0.001$] and Modality match [$F(1,96) = 4.5$; $P < 0.05$] (Fig. 1). However, no interaction reached significance [$F(2,192) = 0.08$; $P > 0.05$]. Scheffe post-hoc tests showed that both old-yes and lure-yes ERP correlates were significantly more positive than new-no correlates ($P < 0.001$). The late right-frontal old/new effect was therefore found. No difference was found between ERP correlates of old-yes (true recognition) and lures-yes (false recognition) answers ($P > 0.05$). Finally, ERPs elicited in the study-test modality-match condition (VV) were significantly more positive than those elicited in the modality-mismatch condition (AV). Therefore, the brain activity registered in this time window (1000–1500 ms) was the only one modulated by modality-match presentation.

Discussion

As expected, a DRM memory illusion effect was found at the behavioural level, with a 45% of false memory rate. The effect of sensory modality-match manipulation could not be found on false memories; it was found, however, on true memories, with words presented in the 'matching' condition being better recognized (72%) than words presented in the 'mismatching' condition (65%). This modality-match effect on true recognition did not confirm the result obtained recently by Mulligan *et al.* [16], who found no modality-match effect on simple recognition tasks (see also Curran and Dien [17]). According to their data, modality-match facilitation seems to arise only when modality is made salient and/or relevant at test (see also Mulligan and Osborn [18]).

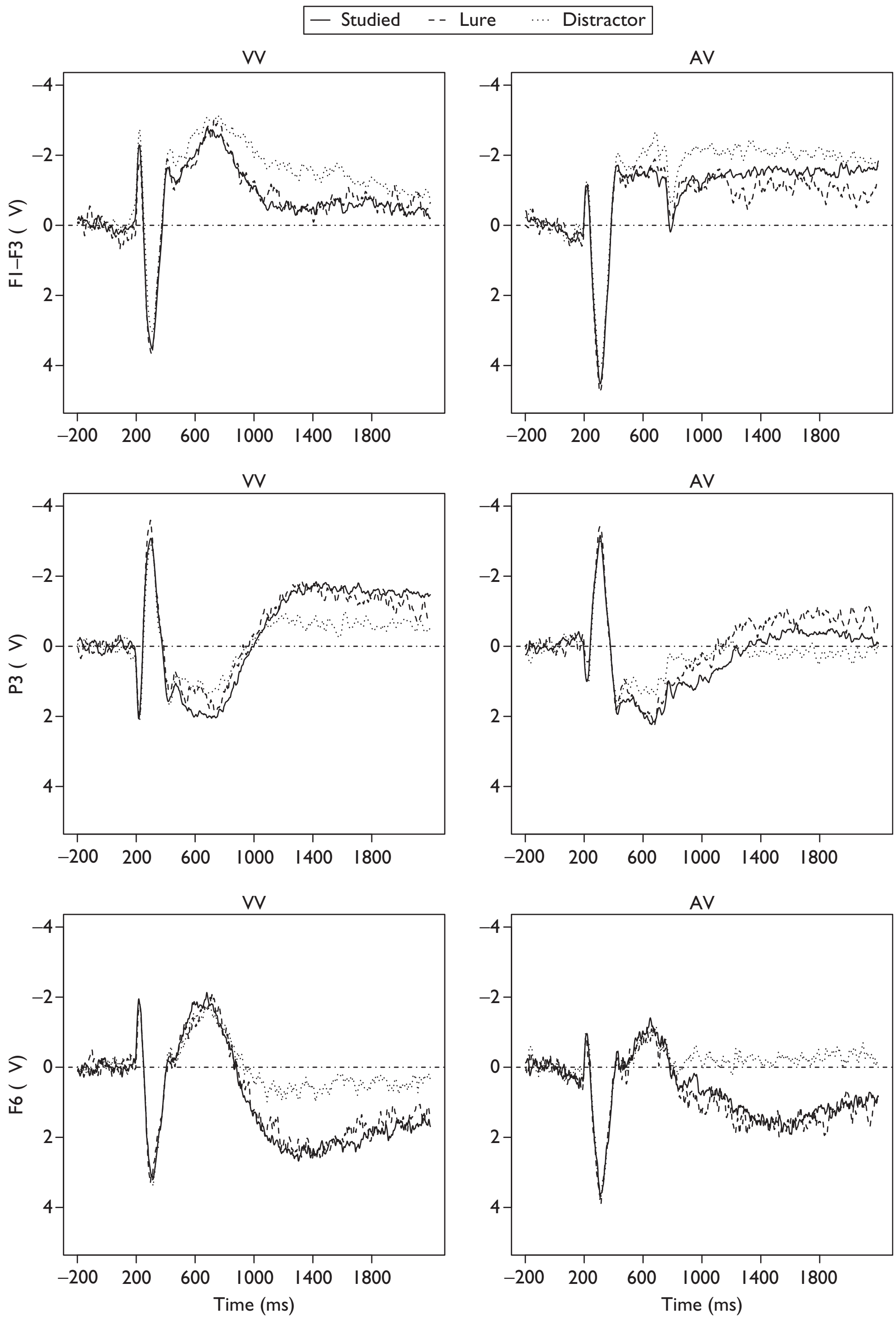
Moreover, our behavioural data did not find any supportive evidence for those DRM studies suggesting that visual presentation at encoding would *per se* lower the false memory rate [19,20]. Rather, our results are more in agreement with some recent papers showing that this effect might be found with some experimental designs, but it is not a general finding [21] (see also Pierce and Gallo [10]). For example, both Smith and Hunt [19], and Cleary and Greene [20] claimed that switching from auditory to visual presentation at study would significantly reduce false memory. However, in their studies, they never used simple recognition tasks; they used either recall, or recognition preceded by recall, or recognition tasks where visual features were made particularly relevant. However, when Smith *et al.* [21] tested performance in a simple recognition task, they could not find any significant reduction in false memories.

ERP components from three main locations were analysed in this experiment: an early (300–500 ms) frontal old/new effect indexing familiarity, a left-parietal old/new effect (400–800 ms) indexing recollection and a later (1000–1500 ms) right-frontal old/new effect, usually associated with postretrieval monitoring.

ERP analysis of the first time window showed a similar FN400 old/new component for true and false recognition and no modality-match effect. According to part of the literature on recognition memory, familiarity builds more on perceptual information than on semantic one; thus, in principle, one could expect presentation modality match to affect the FN400 component [4,5]. The debate, however, is still open on this issue. Curran and Dien [17], for example, conducted an experiment that was very similar to the present one, although they were looking at true recognition only, and obtained results that were very similar to ours in this time window. Their conclusion was that familiarity, as indexed by the FN400 component, is rather an 'amodal' process than a process building on the presentation, again, at test of the same perceptual features coded at study. The present findings support this claim, if possible, even more strongly as ERP correlates of true and false memories basically overlapped. Therefore, data from this first time window show not only that the brain is already able to make an old/new distinction even at these very early stages of recognition and that this is not a mere 'perceptual' effect but also that true and false recognition do not differ in this sense. These findings, in turn, support the idea that semantic information already plays some role at these early stages of recognition memory.

A left-parietal old/new effect, no differences between true and false recognition and no modality-match effect were also found at the second time window (400–800 ms). Replicating what was already found in previous research [15], these data confirm the overlap between ERP correlates of true and false recognition

Fig. 1



Average event-related potential correlates for the 'match' condition [visual–visual (VV)] and the 'mismatch' condition [auditory–visual (AV)] at F1–F3, P3 and F6 electrodes. Studied: 'yes' responses to studied words (true recognition); lure: 'yes' responses to critical lures (false recognition); and distractor: 'no' responses to distractors.

even at this second processing stage, when conscious recollection supposedly comes into play [4,6]. True recognition data are similar to those found by Curran and Dien [17] in this second interval as well.

At the last time window, a right-frontal old/new effect (1000–1500 ms) was found for both true and false recognition, and this supports previous findings [15,17]. In addition, ERPs correlates for the 'match' condition

(VV) were more positive than ERPs correlates for the 'mismatch' condition (AV), although no interaction with item type was found. Only at this late time window was modality-match manipulation therefore detected at the ERP level.

Therefore, sensory modality matching between study and test played a greater role during what is usually identified as the 'monitoring' process than at the earlier stages of recognition memory. The fact that discrimination between 'match' and 'mismatch' condition does not interact with discrimination between true and false memory is an interesting piece of evidence that seems to suggest how false memories can be really experienced 'as if' they were true memories, even when the brain, through monitoring of study episodes, is able to tell apart sensory 'match' and 'mismatch' conditions. Beato *et al.* [15] recently found some similar results manipulating the level of processing in a DRM experiment analogous to the one presented here. In their study, ERPs correlates of true and false recognition memory also overlapped across the three time windows; the effect of the main manipulation was found with true recognition at the behavioural level, but it was only associated with monitoring at the ERP level and there was no interaction with item type.

Taken together, the data from these two experiments seem to suggest a sort of 'inability' of the brain to differentiate between true and false recognition memories at the ERP level, even though at the behavioural level the main manipulation clearly affected only true recognition and not false recognition. The effects of the main manipulation at study (i.e. level of processing or modality-match effects on true recognition) seem to be based more on information from the monitoring process than on information from any other earlier process. These data are quite interesting on their own, but also in relation to the current main theories on DRM illusion [22,23]. We therefore believe that this line of research deserves further investigation.

As for the present study, the fact that the interaction between sensory matching manipulation and true/false memory discrimination can be detected only at the behavioural level and not at the ERP level might seem an inconsistency, but it is not. ERP data show that true and false memories activate overlapping ERP correlates along the three temporal intervals and regions of interest we examined. They also show that only in the last temporal window the brain distinguishes between items in the matching and the mismatching conditions. In turn, behavioural data show how, when one has to take the final yes/no decision, the condition of sensory 'matching' does help, and it does so in the case of true memories, but not in the case of false memories. This is perfectly reasonable as it is only with true memories that the sensory dimension, already activated at monitoring and along which items can be distinguished, can be processed. Therefore, behavioural data are not inconsistent with ERP data. The possibly only reason for the seeming discrepancy between behavioural and ERP data is that the final yes/no decision is the result of additional decision-making factors.

Conclusion

Using the DRM paradigm, the present experiment manipulated the sensory modality of stimulus presentation (auditory vs. visual) in the study phase to analyse the effect of modality match between study and test on true and false recognition. A modality-match effect was found only on true recognition memory and at the behavioural level. At the ERP level, true and false memories could not be dissociated in any of the three time windows that were examined, whereas modality-match manipulation seemed to play an important role only in the final monitoring process.

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Conflicts of interest

There are no conflicts of interest.

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