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ABSTRACT

Identifying faces is a process central for social interaction and a relevant factor in eyewitness theory. False recognition is a critical mistake during an eyewitness's identification scenario because it can lead to a wrongful conviction. Previous studies have described neural areas related to false facial recognition using the standard Deese/Roediger-McDermott (DRM) paradigm, triggering related false recognition. Nonetheless, misidentification of faces without trying to elicit false memories (unrelated false recognition) in a police lineup could involve different cognitive processes, and distinct neural areas. To delve into the neural circuitry of unrelated false recognition, we evaluated the memory and response confidence of participants while watching faces photographs in an fMRI task. Functional activations of unrelated false recognition were identified by contrasting the activation on this condition vs. the activations related to recognition (hits) and correct rejections. The results identified the right precentral and cingulate gyri as areas with distinctive activations during false recognition events suggesting a conflict resulting in a dysfunction during memory retrieval. High confidence suggested that about 50% of misidentifications may be related to an unconscious process. These findings add to our understanding of the construction of facial memories and its biological basis, and the fallibility of the eyewitness testimony.

Introduction

Face perception plays a critical role in social interactions. It requires not only to perceive faces, but also to constantly identify individuals (Haxby, Hoffman, & Gobbini, 2000). However, memory is a constructive and dynamic process that can make mistakes (Hardt, Einarsson, & Nader, 2010; Schacter, Norman, & Koutstaal, 1998).

A common error or memory distortion is false recognition, which occurs when a person points out that a new stimulus (or event) has been seen before. A number of studies have been designed to try to understand memory distortions using words, abstract figures and object pictures as stimuli, (Schacter, Buckner, Koutstaal, Dale, & Rosen, 1997; Slotnick & Schacter, 2004) however only a few have used faces. This kind of error in the facial recognition domain is critical in eyewitness identification after a crime has been committed because they are often essential to identifying, charging, and

ultimately convicting perpetrators of crime and in some cases, may provide the sole piece of evidence against those individuals (Hart, 2003). This can result in wrongful convictions while the true criminal goes unpunished (Wells & Olson, 2003). Eyewitness misidentification is the greatest contributing factor to wrongful convictions proven by DNA testing, playing a role in more than 70% of convictions overturned through DNA testing nationwide (The Inocence Project, 2017). For this reason, eyewitness theory focuses on false recognition (Lindsay, Ross, Read, & Toglia, 2013).

Lately, it has been considered that cognitive neuroscience could contribute to addressing memory in the courtroom (Schacter & Loftus, 2013), for example, by classifying activity patterns of areas involved in a facial recognition (Rissman, Greely, & Wagner, 2010). In addition, a number of studies have identified some areas including the cingulate gyrus, the orbitofrontal area and the amygdala as related to facial false recognition process. These studies used morphed faces that

were applied in the Deese/Roediger- McDermott (DRM) paradigm (Roediger & McDermott, 1995) (Iidaka, Harada, Kawaguchi, & Sadato, 2012; Iidaka, Harada, & Sadato, 2014). It is important to note that DRM paradigm induces memories called related false alarms (or related false recognitions), because these memory representations are related to the stimuli previously shown (Garoff-Eaton, 2006).

False recognitions in a police lineup, however, could be considered unrelated false alarms (or unrelated false recognition), because these representations are not directly related to stimuli previously shown (as in contrast to the DRM paradigm). So, in this case, unrelated false recognition would be considered when a subject indicates having seen a face before that was shown without the purpose of trying to elicit false memories. Therefore, it is possible that compared to related false alarms, unrelated false alarms may arise from different cognitive processes involving distinct neural circuits (Garoff-Eaton, 2006).

A previous study compared the activity obtained during unrelated false facial recognition to a baseline (control or fix point condition) (Hofer et al., 2007). However, that analysis cannot inform if those areas are involved only in false recognition or if they participate in other memory processes such as recognition or correct rejection, e.g. fMRI studies using non-facial stimuli have found that neural activity related to true and false memories have common neural areas or similar activity patterns (Schacter, Buckner, Koutstaal, Dale, & Rosen, 1997; Slotnick & Schacter, 2004). So, there are two important pieces of information lacking from previous studies on unrelated false recognition. The neural activity associated to true and false memories could share common neural areas (Scharter et al., 1997; Slotnick & Schacter, 2004), or their neural activity could show different activation levels, e.g. increased activation in the frontal cortex during false memory (Cabeza, Rao, Wagner, Mayer, & Schacter, 2001; Garoff-Eaton, Kensinger, & Schacter, 2007; Slotnick & Schacter, 2004). Thus, it is still unknown if there are areas carrying on processes uniquely involved in unrelated false facial recognition. Identifying if there are functional areas distinctively involved in this memory distortion is essential for understanding the underlying cognitive processes of unrelated false facial recognition, which directly pertains to a lineup situation.

Based on this information, here we wanted to explore the hypothesis that there are unique activations related to false facial recognition. To do so we obtained BOLD signals from subjects performing a facial memory tasks in an MRI scanner. We then subtracted the activations obtained during false recognition (false memories) from those obtained during activations associated to recognition and correct rejection (true memories). This effectively isolated activations unique to false recognition by excluding the shared areas in true memories.

Additional to this analysis, we considered it important to evaluate the degree of confidence in the participant's responses (i.e. whether the participant is sure of the answer given). Confidence could provide information on the awareness of mental states (Dienes & Perner, 2001) and to determine if the memory errors occur at an unconscious level as other studies have proposed (Slotnick & Schacter, 2004). Although this variable has been widely explored in memory research (Henson, Rugg, Shallice, & Dolan, 2000), it has been neglected in most studies about false memories.

In summary, to explore the neural basis of false facial recognition, we compared participants' BOLD activations associated to correct memory responses (recognition and correct rejection) vs. false memories (erroneous responses). By making this contrast we inferred specific functional areas related to false facial recognition and their relation to the participant's response awareness, which could have profound implications on forensic research and eyewitness theory (i.e. Lindsay et al., 2013).

Method

Participants

Eighteen healthy volunteers (10 female) took part in the experiment (mean age = 24.52 range = 19–36 years old). All participants were right-handed, had normal or corrected to normal vision, with no history of present or past neurological illness. All participants gave written consent according to the Declaration of Helsinki (BMJ 1991; 302: 1194) prior to their participation and have been fully anonymized.

The study was approved and conducted following the guidelines of the Research and Ethics Committee of the Medicine Faculty of Universidad Nacional Autónoma de México (UNAM) (Project N° 0015–2009). Before performing the fMRI experiment participants completed the Edinburgh Handedness Inventory, and the Scale of the Center for Epidemiological Studies-Depression (CES-D). All participants reported having no history of any mental condition, including depression as confirmed by the CES-D.

Stimuli preparation

From 350 photographs taken from Mexican volunteers, 240 were selected for this study (120 females and 120 males). To avoid external variables, these images were edited, including conversion to gray scale and cropping

to an oval template around the face. A noise stimulus was built by fragmenting and randomizing one of the images to be placed within the same oval template as the rest of the facial pictures.

Experimental procedure

Training. Participants were trained to respond to each task before getting inside of the MRI bore. Feedback was used during the training. Once they obtained 90% of correct answers they proceeded to start the experiment. Stimuli shown during training were not used in the subsequent tasks. The presentations of the learning tasks were counterbalanced across subjects.

The fMRI experiment consisted of an event related design with 4 runs as described below.

Learning task.

Two sequences were presented. Each run had 40 target faces (each repeated 3 times across the run in a semi random fashion), 40 new distractor faces and 20 noise stimuli equally distributed across the run. Each stimulus was presented during 2000 ms. Black screens were shown with a jittering of 2000 to 6000 ms. Each sequence had a total duration time of 7.5 minutes. During each run, participants were asked to press a button in a button-box placed in the right hand if the current face picture had been shown before, and to

press another button if not. The buttons were counter-balanced across subjects. If a noise stimulus appeared they were required to press both buttons simultaneously (Supplementary Material).

Recognition memory test.

A recognition memory run including an evaluation of the confidence response followed each learning run. On each recognition memory run, 40 target faces (seen before), 40 new distractor faces, and 20 noise stimuli were included. All of them were presented during 2000 ms. A letter C cue appeared during 2000ms following each face presentation. Black screens were shown with a jittering of 2000 to 4000 ms. The recognition memory runs had a total duration of 10.2 minutes. During these runs, participants were asked again to indicate with the button-box if the face presented had been shown before. After each stimulus a letter C cue was presented and they had to indicate the confidence (high or low) of their previous response. As before, they had to press two buttons simultaneously if the stimulus was noise (see Figure 1).

Image acquisition

Images were taken with a 3.0 T Discovery MR750 General Electric (GE Medical Systems, Waukesha,
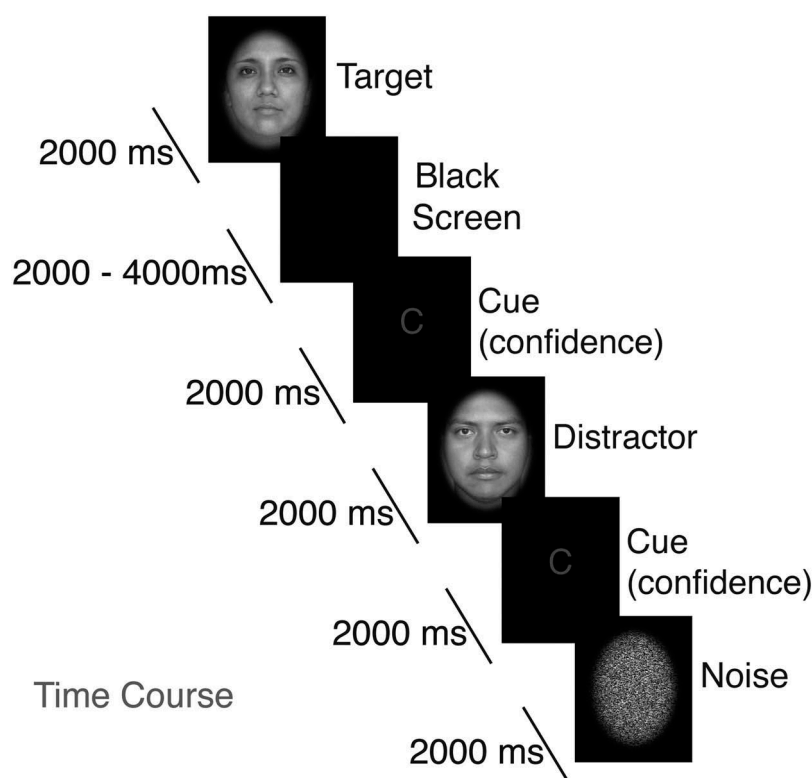
Figure 1. Recognition memory test. Example illustrating the presentation timing of different stimuli during one of the recognition memory tests. C represents the cue to confidence response.

Wisconsin, USA) scanner with a 32-channel head coil at the Instituto de Neurobiologia, UNAM. T2 weighted slices depicting BOLD signal were obtained during functional scans (35 slices with zero gap, flip angle of 30°, TR = 2000 TE = 40 ms, 64 × 64 matrix size, 256 × 256 mm field of view, in isometric voxels of 4 × 4 x4 mm^3). For each participant, high- resolution T1- weighted anatomic images were also collected with an FSPGR sequence (256 × 256 matrix, field of view 256 × 256 mm, in isometric voxels of 1x1x1 mm^3). The stimuli were presented with a Nordic NeuroLab system display at an SVGA, 800 × 600 pixel aspect ratio, 85 Hz, field of view 30° horizontal, 23° vertical.

Fmri data analysis

Preprocessing. fMRI preprocessing included brain extraction, cubic spline ascending interleaved slice scan time correction, trilinear/sinc interpolation 3D motion correction, spatial smoothing (6 mm full-width at half-maximum Gaussian kernel), and temporal filtering (band pass, 0.01–0.08 Hz) using BrainVoyager 2.8 version for Windows (www.brainvoyager.com). After rigid alignment of fMRI images to structural images, spatial normalization of fMRI images to the Tailarach space was achieved using the transformation field acquired during the structural image registration. The first 6 volumes (12 s) of each scan were removed to minimize the effects of magnetic saturation. One participant was excluded from further analysis because of excessive movement during the experimental scan.

Defining facial processing ROIs (localizer analysis).

A general linear model (GLM), including a two-gamma hemodynamic response function, was modelled for the face and noise stimuli across the learning runs. To localize the areas involved in face processing, the BOLD activations resulting from the scrambled faces presentations were subtracted from those obtained during the face epochs using Random Effects Analysis (RFX), and a false discovery rate (FDR) correction with a threshold of q < 0.05, and a uncorrected p value of .001 (Fox, Iaria, & Barton, 2009); thus, allowing identification of regions of Interest (ROI) related to facial perception of the Core and Extended Systems (Gobbini & Haxby, 2007; Haxby et al., 2000), in Talairach coordinates (Rossion, Hanseeuw, & Dricot, 2012; Talairach & Tournoux, 1988). Then, we proceeded to analyze the beta values from the BOLD activations of the Core and Extended Systems during false recognition (false alarm), correct rejection, and true recognition (hit) in the selected ROIs (in localizer analysis). The data from these three conditions were then compared using one-way repeated measures ANOVA.

Analysis of differential activations.

A second level analysis was applied to find the functional areas with differential activation levels during facial false recognition. This approach is based on the knowledge that true and false memories can share common neural areas (Schacter et al., 1997; Slotnick & Schacter, 2004). The idea is to identify functional areas of false recognition as a result of contrast in the activation related with false recognition (false alarms) from that associated with recognition (hit) and correct rejection. To carry out this contrast black screens and noise stimulus events were used as base line. In this analysis, as in the localizer analysis, a general linear model (GLM), including a two-gamma hemodynamic response function, was modelled for the face and noise stimuli across four runs (two learning tasks and two recognition memory tests). A Random Effects (RFX) was used, with a p = 0.05 value and a cluster correction of 26 voxels, given by the Cluster level statistical threshold estimator in Brain Voyager (www.brainvoyager.com), with 1000 itinerations of montecarlo cluster thresholding.

A subsequent analysis was carried out on the selected ROI´s (10X10X10 voxels centered at local maxima). Activity related to each condition (recognition, correct rejection and false recognition) was analyzed with a one-way repeated measures ANOVA and a Fisher´s post-hoc test at alpha value of 0.05.

High confidence VOI´s.

In order to be more specific about of the nature of the activity identified through the previous analysis, we investigated if it was related to events of high or low confidence dividing the responses based on their degree of it. Then, we proceeded to analyze the activation levels during the high confidence responses, discarding the low confidence responses associated with memory uncertainty during the identification process. The beta values from high confidence responses of the three conditions were later analyzed using a one-way repeated measures ANOVA.

IBM SPSS statistics v 24 program was used for all ANOVA analysis.

Results

Behavioral data

Responses for the target faces were 70.52% (28.20 ± 2.18 SEM) for recognition (hits), and 26.25% (10.5 ± 2.11) for forgetting (misses). While for the distractor faces, the correct rejection was 54.41% (21.76 ± 1.40), and the false recognition (false alarm) was 41.54% (16.61 ± 1.32). A one-way ANOVA showed significant differences between conditions including

recognition, correct rejection and false recognition: F (2, 66) = 19.402, p < .001, with a Sensitivity (d′) mean of 0.86 ± 0.11 SEM.

The average reaction time (RT) for recognition responses was 1220 ± 5.02 ms, for misses was 1405 ± 5.06, for correct rejection was 1370 ± 5.09 ms, and for false recognition responses was 1300 ± 4.94 ms. A Linear Mixed Model Random Effects analysis was carried out (for recognition, correct rejection, and false recognition responses) and showed significant differences among all groups t(33) = 16.47,p < 0.0. IBM SPSS statistics v 24 program was used (see Figure 2).

Confidence responses for the recognition responses had 81.83% (46.54 ± 4.64) of high confidence and 18.16% (10.32 ± 1.32) of low confidence. Miss responses had 59.73% (11.66 ± 1.54) of high confidence and 40.26% (7.86 ± 0.89) of low confidence. (Correct rejection, had 57.59% (27.32 ± 3.26) of high confidence and 42.40% (15.04 ± 2.7) of low confidence. Finally, false recognition had 57.60% (20.22 ± 2.3) of high confidence and a 42.39% (14.88 ± 1.78) of low confidence (see Figure 3).

fMRI data
Defining facial processing ROIs (localizer analysis).
We localized the facial perception Core System brain areas (Fox et al., 2009; Haxby et al., 2000), including the posterior right Fusiform Face Area (rFFA) (38, −67, −14, BA 19), posterior left Fusiform Face Area (lFFA) (−38, −67, −14), right Occipital Face Area (rOFA) (28, −80, −16) and left Occipital Face Area (lOFA) (−24, −80, −13, BA 19). The analysis also localized areas related to the Extended System (Haxby et al., 2000). The identified areas were the right Amygdala (17, −16, −18, BA 28) and the right Insula (BA13) (35, 16, 6).

A one-way ANOVA analysis on the betas derived from the BOLD activations comparing the values from all these ROI′s related to each condition (false recognition vs recognition vs correct rejection) did not show any differences, rFFA, F(2,66) = .92631, p = .40110, lFFA, F(2,66) = .40659, p = .66757, rOFA, F(2,66) = 1.8669, p = .16267, lOFA, F(2, 66) = 1.0492, p = .35597, right Amygdala, F (2, 66) = 1.0068, p = 0.37094 and right Insula, F(3,99) = 1.7026, p = 0.17041.
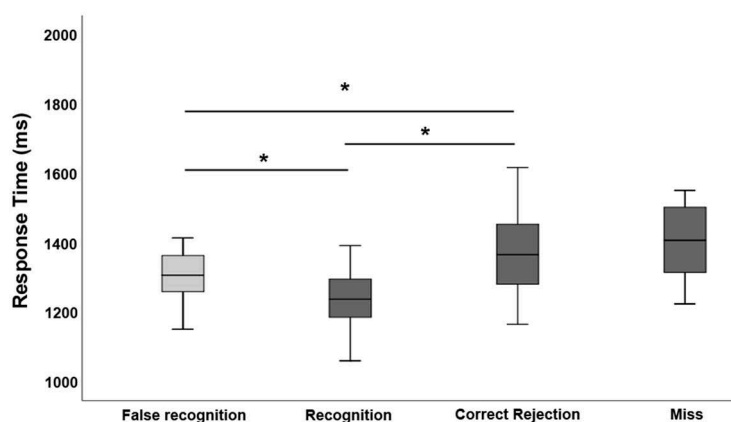
Analysis of differential activations. The areas identified through the analysis of differential activations for false facial recognition versus recognition and correct rejection were the right precentral gyrus, F (2,66) = 12.941, p = 0.00002, and the right cingulate gyrus, F (2, 66) = 9.4426, p = 0.00025 (see Figure 4). The same analysis did not show areas with a significant greater activity associated to recognition or correct rejection.

High confidence VOI′s. A similar analysis of differential activations during high confidence responses on the areas involved in false recognition did not show any significant differences.

Discussion

The present study investigated neural areas involved in false facial recognition through memory assessment of faces in an fMRI setup. Using an analysis of differential activations, we identified the right precentral gyrus and the right cingulate gyrus as areas showing distinct activations during false facial recognition events. In addition, reaction time (RT) and response confidence to facial recognition were evaluated: both were taken as indicators to understand the process associated with the functional areas identified.

The initial approach was to localize the face perception areas of the Core System and the Extended

Figure 2. Reaction times across memory conditions. Box plot showing minimum, first quartile, median, third quartile, and maximum. * = (p < 0.05).
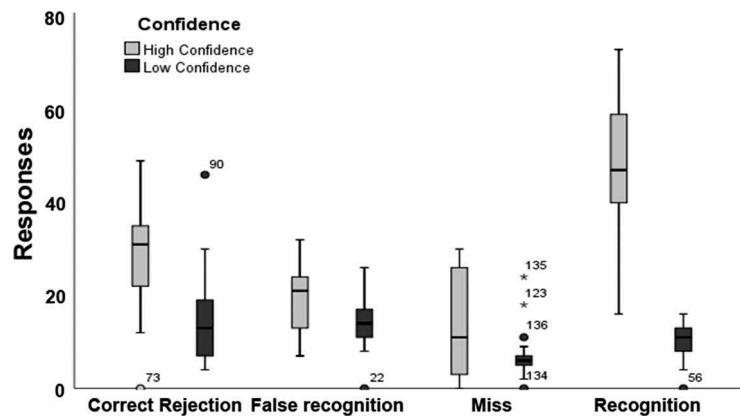
Figure 3. Confidence responses during recognition memory test. Boxplot shows the amount of confidence responses, high or low (based on total responses of each kind of condition: false alarm, recognition and correct rejection).
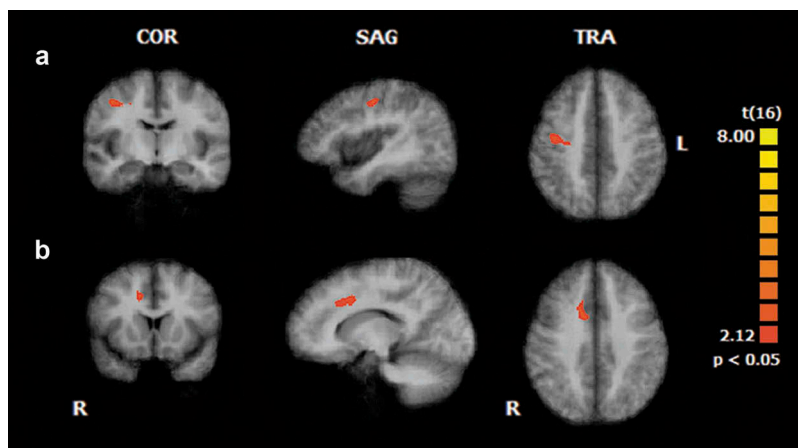
Figure 4. Hemodynamic activity related to false facial recognition obtained through analysis of differential activations. (a) Activity in the right precentral gyrus (x = 40, y = −10, z = 44, BA 6). (b) Activity in the right cingulate gyrus (x = 14, y = 12, z = 37, BA 32). Talairach coordinates were used (Talairach and Tournoux, 1988). P < 0.05 corrected for cluster size. Cluster correction of 26 voxels.

System as previously described (Gobbini & Haxby, 2007; Haxby et al., 2000). These areas included the Core system, (rFFA, lFFA, rOFA and lOFA). However, the activation in the Superior Temporal Sulcus (STS), usually included within the Core System, was not found, probably because the localizer used is effective in identifying FFA and OFA but not STS (Fox et al., 2009). It has been reported that STS is more sensitive to facial expressions and gaze direction (Engell & Haxby, 2007), and given the nature of our stimuli (standardized- neutral face and same gaze direction), our stimuli did not evoke enough activation in this area. Finally, we also identified areas related to the Extended System such as the amygdala (BA 13) and insula (Haxby et al., 2000).

The analysis of the beta values from the BOLD activations of the Core and Extended Systems during false recognition (false alarm), correct rejection and true recognition (hit) in the selected ROIs (in localizer analysis) did not yield differences between false recognition and the other two conditions within these areas. It should be noted that previous studies using other techniques such as BOLD adaptation have suggested sensitivity to facial identity in areas like FFA (review Andrews & Ewbank, 2004; Nestor, Plaut, & Behrmann, 2011). However, those studies did not attempt to analyze if activity during false recognition trials could also be linked to specific areas.

Using the analysis of differential activations, we identified activity increases in the right precentral gyrus and the right cingulate gyrus as areas whose activation could be related to false facial recognition. It could be argued that since these areas are closely related to motor function the activity found could be a motor related artifact. However, it should be noted that both baseline and scrambled conditions involved motor responses similar to the responses elicited during the critical tests. Since activations from both baseline and

scrambled conditions were taken into account during the analyses, it is highly unlikely that the observed activations are an artifact.

Previous facial recognition studies support our findings, for example, higher overall activity in prefrontal cortex related to false recognition has been found using event-related potentials (Endl, Walla, Lindinger, Deecke, & Lang, 1999). Additionally, the right precentral frontal gyrus has been related to information retrieval (Bernstein, Being, Siegenthaler, & Grady, 2002), although, those reports did not include a discussion on the relevance and functionality of this area. Other studies testing explicit memory tasks such as ours, have suggested that the right prefrontal cortex is involved during an information retrieval effort (Schacter, Alpert, Savage, Rauch, & Albert, 1996) as well as in the monitoring and recollection of contextual information (in dorsal regions) (Henson, Shallice, & Dolan, 1999). It also should be noted that the precentral gyrus activity is related to a fronto-parietal attentional network, linked to more complex processes such as reflective or voluntary attention and the analysis of objects (Corbetta, 1998).

The results also showed the right cingulate gyrus as a relevant area involved in false recognition, confirming previous findings (Hofer et al., 2007; Iidaka et al., 2012). The right cingulate gyrus has also been linked to episodic information and the visual attention recovery mechanism (Lepage, Ghaffar, Nyberg, & Tulving, 2000). This activity has been found during false memory of words and interpreted as an association between performance monitoring and response conflict (Iidaka et al., 2012; MacDonald, Cohen, Stenger, & Carter, 2000; von Zerssenet, Mecklinger, Opitz, & von Cramon, 2001). A modified version of the standard false memory paradigm using morphed faces pictures (lures) to induce false memory, also found that the anterior cingulate cortex is involved in false recognition (Iidaka et al., 2012). However, our results differ from that report in two aspects: firstly, they suggested that the activity in the amygdala and orbital cortices was associated with the degree of familiarity of items. In particular, false responses to "lure" items evoked a level of activity in the amygdala between the levels produced for correct or incorrect responses to "true" items. Here we didn't identify any activity in the orbital cortex or the amygdala that confirms that such activity is specifically related to recognition. Secondly, our results associated the right precentral gyrus activity to false recognition while they didn't report it in their results. It is possible that these discrepancies arise from the differences in the paradigms used. They constructed false memories by using similar stimuli (i.e. related false alarms) while

we evaluated the normal memory performance without interfering externally on the morphology of the items (i.e. unrelated false alarms). This difference could have an effect on the neural areas involved, as there is evidence that related and unrelated false alarms could rely on different cognitive processes and neural areas to recover information (Garoff-Eaton, 2006). Hence our study would highlight the functional areas relevant for unrelated false memories.

RT is another indicator of cognitive processing. It refers to the time between the stimulus presentation and the subject response. The RT can be helpful to understand the mental activity by determining the components of instances on the process through the time (Stenberg, 1969). The false recognition RT was different from both, the correct rejection and the recognition RTs, so it is possible to suggest that there are different processing demands between those three instances. It is important to clarify that we do not attempt to interpret that RT is an indicator of effort in information retrieval, nor as a monitoring indicator, because as other studies have suggested, both cases imply longer response times, making it difficult to differentiate between them (Henson et al., 2000).

To reach a deeper understanding of the processes related to false recognition instances, we analyzed them in relation to the degree of response confidence. This analysis showed no association to a specific VOI. However, a caveat of this fMRI analysis is that the SNR ratio decreased as a consequence of losing around half of the events (after splitting the groups by high and low confidence), so the activations of this analysis could not reach statistical significance due to these changes. Nevertheless, the same observation that subjects had high confidence in around 50% of their responses, suggests that false recognition may come from a memory error which, at least, half of the time is an unconscious process. Other studies support this assumption, for example, it has been suggested that under some conditions there is no within subject relationship between confidence and accuracy (Dienes & Perner, 2001), suggesting that subjects are not conscious of their knowledge state. Accordingly, our study supports previous assumptions about false memories claiming that false recognition may not be accessible to consciousness (Schacter & Slotnick, 2004).

Therefore, our interpretation about the role of these areas is: a) These areas have been involved in response monitoring and/or increased attention; then, in the current context the increased activity could be the result of a confusion or a conflict process during the monitoring of the face selection response during information retrieval. B) False recognition RT suggests that

this is a different process from true memories that does not involve the same process as seeing a new face (correct rejection) or seeing a face previously encountered (recognition), further supporting the memory conflict hypothesis (review, Iidaka et al., 2012). C) Finally, the confidence responses results suggest that in this case about half of the recognition events could be an unconscious process (given the percentage of high confidence).

In conclusion, our research was focused on exploring the neural basis of unrelated false facial memories. The results show activation of specific neural areas that could be involved in a conflict or confusion present even when people declare to be sure about having seen a face before. However, further research is needed to reach a deeper knowledge about the function of these areas on false recognition. Our results represent biological evidence about the false facial recognition process and hence about the fallibility of mnemonic process during eyewitness recognition, supporting eyewitness theory with all its legal implications. Because they are often essential to convicting perpetrators of crime (Hart, 2003), eyewitnesses' testimony should not be considered an infallible proof because it could result in wrongful convictions (Wells & Olson, 2003).

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