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Mapping the apetitive and aversive systems with emotional pictures using a Block-design fMRI procedure

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Negative emotional pictures from the International Affective Pictures System (IAPS) have been successful in mapping brain areas related to the aversive system. However, the capacity of positive emotional pictures to study the brain areas related to the appetitive system (i.e., nucleus accumbens, prefrontal cortex) is less established. In this study, we used a block fMRI design to investigate this issue, including emotional pictures as background while participants performed a vowel-consonant discrimination task. Importantly, participants were heterosexual males and all positive pictures were related to erotic couples, opposite-sex erotica, or romantic scenes. Negative pictures were similar to those used in previous studies. Results were consistent with previous studies using event-related designs, showing activation of amygdala, lateral prefrontal cortex, and occipito-temporal areas, but positive pictures showed a significant activation in the left nucleus accumbens. These findings provide evidence of the utility of block designs in emotional research (positive emotional pictures).

Estudio del sistema apetitivo y sistema aversivo con imágenes emocionales utilizando el procedimiento de diseño de bloques en RMf. Las fotografías con contenido emocional negativo del International Affective Pictures System (IAPS) son una buena herramienta para el estudio de las áreas cerebrales relacionadas con el sistema aversivo. En cambio, la capacidad de las fotografías con contenido emocional positivo para el estudio de las áreas cerebrales relacionadas con el sistema apetitivo (por ejemplo, núcleo accumbens, cortex Prefrontal) está menos establecida. En este estudio se ha utilizado un diseño de bloques con la técnica de RMf para investigar las áreas cerebrales involucradas en el procesamiento de imágenes con contenido emocional, presentándolas como fondo mientras los participantes realizaban una tarea de discriminación vocal-consonante. Todos los participantes eran hombres heterosexuales y las imágenes positivas presentadas estaban relacionadas con escenas eróticas en las que aparecían parejas, fotografías eróticas de personas de otro sexo y escenas románticas. Las imágenes negativas eran similares a las utilizadas en estudios previos. Verificando resultados previos con RMf, para el procesamiento de imágenes negativas se obtuvo activación en la amígdala, en el córtex prefrontal lateral y en áreas occipitotemporales. Para las imágenes con contenido positivo, los resultados mostraron una activación significativa en el *núcleo accumbens*. Estos datos aportan evidencia sobre la utilidad de los diseños de bloques en la investigación sobre el procesamiento emocional (imágenes emocionales positivas).

Most of the recent studies designed to investigate picture emotional processing with fMRI has employed event-related designs. These designs are better than blocked designs to estimate the shape of hemodynamic response but worse to detect brain areas involved in a determinate process (Huttel, Song, & MCCarthy, 2004). Importantly, event-related designs allow to mix different experimental conditions and post-hoc trial sorting, but requires the use of a small subset of stimuli. Methodologically, blocked and event-related designs differ in their sensitivity to capture transient and sustained activations. While blocked analyses can potentially detect sustained and transient activations, event-related analyses are rather sensitive for item-related transient neural processes but ignore sustained activations (Vischer et al., 2003). Then, it would be interesting to study the concordance between both kinds of design, because then it can be assumed that both reflect similar psychological processes.

The use of blocked designs has been criticized in emotional research because they lead to emotional learning due to the repetition of stimuli of the same category (Morris & Dolan, 2004). Most of the explicit fMRI tasks require direct judgements on emotional stimuli which may confound the expectancy of emotion with processing of the stimuli. One system to partially overcome this problem using a blocked design is to use emotional stimuli as background not relevant to complete the cognitive task. With this

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approach we have designed an fMRI task with emotional stimuli as background, using a simple vowel-consonant discrimination task as the target task.

A frequently used, standardized method to evoke and assess emotions with respect to dimensions of arousal and valence, is the International Affective Picture System (Lang, Bradley, & Cuthbert, 1997). In this paradigm, a large series of pictures with emotional content were rated and validated in different cultural contexts. It has been proposed both that the unpleasantness and pleasantness of a stimulus represent polar opposites of the psychophysiologic dimension of valence and that positive and negative valence are two separate dimensions (Cacioppo & Berntson, 1994) and thus may be mediated by different brain circuits. Functional neuroimaging studies have served to identify brain areas of the emotion circuitry including the amygdala, the orbitofrontal cortex, the insula and the anterior cingulate, especially when processing aversive pictures (Irwing et al., 1996; Lane, Fink, Chau, & Dolan, 1997; Lane, Chau, & Dolan, 1999). However, less studies has been dedicated to investigate brain areas associated with processing of positive pictures. Candidate structures for the mediation of responses associated with the positive valence of a stimulus are the ventral striatum (i.e. nucleus accumbens) and orbitofrontal cortices, but no study with IAPS material has reported both activations.

The less capacity of neuroimaging studies to activate brain areas involved in their processing of pleasant pictures may come from different sources. One important factor is intersubject variability for the evaluation of pictures, that is greater for positive than negative pictures (i.e. greater standard deviation in positive emotional judgement). In other words, judgement of pleasantness for most of positive pictures of IAPS stimuli had a greater variability (i.e. standard deviations) than negative pictures. As a small subset of positive images are typically used in fMRI event-related designs, more of them may not be enough to activate brain areas involved in positive emotions in all participants. One way to solve this problem already investigated in behavioural (Bradley, Codispoti, Sabatinelli, & Lang, 2001) and neuroimaging studies (Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004) is to subcategorize positive pictures. In this sense, some research have shown that pictures with erotic and sexual content were more pleasant and yielded stronger brain activations for males than females (Hamann, Herman, Nolan, & Wallen, 2004).

The present study was designed to investigate the processing of emotional pictures in group of heterosexual males using a blocked fMRI design. The task consisted of viewing pictures of the IAPS as background while the participant was involved in a vowel-consonant discrimination task. Participants were explicitly informed that background pictures were not relevant for the task. Pictures were classified according to their valence in negative, neutral and positive. In the case of positive pictures, and because previous had revealed the efficacy of these pictures to activate brain areas involved in positive emotions in males (Aharon et al., 2001; Sabatinelli et al., 2004), we only selected pictures with sexual and erotic content. We expected that brain areas involved in processing of negative pictures were similar to those previously described using event-related fMRI designs. We also hypothesized that positive stimuli with erotic and sexual content will activate the orbitofrontal cortex and the ventral striatum.

Methods

Participants

Fourteen heterosexual, right-handed males (mean age: 28.8 years) were entered into the study. Participants gave written consent and participated in the study according to the guidelines of the Committee of Human Studies of the University Jaume I. They received 100 € for their participation.

Stimulus materials and design

One hundred and fifty pictures were drawn from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, NIHM, 1999). For the experimental trials, there were three categories of 50 stimuli, classified as a function of the emotional or affective valence: neutral, unpleasant and pleasant. Contents of neutral stimuli included inanimate objects. Unpleasant stimuli were related to mutilations, murdered people, human threat, guns, etc. Finally, all pleasant stimuli were related to erotic couples, opposite sex erotica or romantic scenes. According to norming studies conducted in large Spanish samples (Moltó et al., 1999; Vila et al., 2001), which have yielded comparable results to norming studies in USA (Lang et al., 1997), mean valence ratings were 2.66 (SD= 0.77) for unpleasant pictures, 7.56 (SD= 0.37) for pleasant stimuli and 5.20 (SD= 0.46) for neutral stimuli.[1] Mean arousal scores were 6.33 (SD= 0.99), 6.52 (SD= 0.90). and 3.33 (0.74) for negative, positive and neutral pictures, respectively.

The task was programmed using Presentation software (Neurobehavioral systems, inc). Original digitized IAPS pictures were redigitized at 800×600 using Adobe Photoshop with black framing where needed. These pictures displayed inside the scanner using Visuastim goggles (Resonance Technologies, Inc). Participants were told that they were going to do a letter discrimination task and that pictures were used as background without having any relevance for the task. Each picture was presented for 2.5 seconds with an interstimulus interval of 500ms. White letters inside a small black square (3×3 mm) were presented 500 seconds after the picture in the middle of the screen during 2 sec. until picture disappeared. These letters could be consonants or vowels. Subjects' task was to raise their index finger from his dominant hand when a vowel appeared on the screen (30% of trials, three per block), such than an evaluator could assess subject performance. A total of 150 pictures were presented[1] (50 for each emotional category), these pictures were presented in blocks of 10 pictures of the same affective content, in the following order: N, U, P, N, P, U, N, U, P, N, P, U, N, U, P (N, neutral; U, aversive; P, appetitive). Each block was 30 seconds long and total task duration was of 7.5 minutes.

Image acquisition

Blood oxygenation level dependent (BOLD) fMRI data were acquired on a 1.5T Siemens Sonata system. Subjects were placed in a supine position in the MRI scanner. Their heads were immobilized with cushions to reduce motion artifact. The stimuli were directly presented using goggles Visuastim XGA with a resolution of 800X600. Vision correction was used when necessary.

For each subject, a series of conventional structural images was first collected to provide detailed anatomical information. Gradient echoplanar (EPI) fMRI images performed in 20 axials slices (matrix size 128×128, FOV 24 cm. TE= 40 ms, TR= 3000; thickness= 5 mm; gap= 2 mm) positioned parallel to AC-PC line covering all the brain. A whole brain high resolution 3D- Gradient Echo (FSPGR) T1-weighted anatomical reference scan was acquired during the same scanning session (TE 4.2 ms, TR 11.3 ms, FOV 24 cm; matrix= 256×256×124, 1 mm-thick sagittal images). The entire session, including both structural and functional sequences, lasted 20 minutes.

Data analysis

Functional magnetic resonance imaging data were statistically analyzed using Brain Voyager QX (v 1.3.8 University of Maastricht, Maastricht) software. Scans of each individual were realigned to the first scan, slice-time corrected and subsequently co-registered to the anatomical images manually and normalized into Talairach space (Talairach & Tournoux, 1988) and resampled into 3-mm isotropic voxels. A 6-mm FWHM Gaussian kernel was used to spatially smooth the data before the group analysis was carried out.

Model estimation was convolved with canonical haemodynamic response function at a fixed effects level using a General Lineal Model (GLM). Random effects analyses (RFX) were performed at a second stage for every contrast according to the proposed hypotheses. Group activation related to the task were obtained from a one sample t-test ($p<0.005$, uncorrected). Differential activation contrasts in the experimental task was tested with a two-sample t-test ($p<0.005$, uncorrected), between

Table 1
Brain activation sites during processing of positive and negative pictures

		Positive > Neutral					Negative > Neutral				
Brain activation site	**H**	**BA**	**X**	**Y**	**Z**	**t**	**BA**	**x**	**y**	**z**	**t**
Inferior Frontal Gyrus dorsolateral)	R						45	48	18	13	4,74
Inferior Frontal Gyrus (Dorsolateral)	L						9	-41	4	30	5,93
Inferior Frontal Gyrus (Dorsolateral)	L						46	-41	34	10	5,10
Inferior Frontal Gyrus (ventrolateral cortex)	L	47	-40	24	-19	4,66					
Inferior Frontal Gyrus (orbitofrontal cortex)	L	47	-22	17	-13	4,54	47	-25	15	-20	4,91
Inferior Frontal Gyrus (orbitofrontal cortex)	L	47	-29	16	-18	4,43					
Superior frontal Gyrus	L						6	-5	8	51	4,62
Middle Frontal Gyrus	R						6	38	1	39	4,49
Middle Frontal Gyrus	L	6	-35	10	47	4,48	9	-28	33	35	4,47
Middle Frontal Gyrus	L	6	-37	28	15	4,73					
Precentral Gyrus	R	4	29	-19	44	4,62					
Precentral Gyrus	L	4	-48	-12	38	4,31					
Superior Temporal Gyrus	R		33	3	-15	5,82	38,41	38	3	-21	4,42
Superior Temporal Gyrus	L	38	-30	13	-25	5,38	38,13	-32	5	-21	4,70
Superior Temporal Gyrus	L						38,13	-51	-45	21	4,48
Middle Temporal Gyrus	R	21	57	1	-12	4,92	21	56	2	-12	4,80
Middle Temporal Gyrus	R	39	41	-57	18	4,34	39	44	-55	9	4,48
Middle Temporal Gyrus	L						39	-42	-56	9	5,39
Lingual Gyrus	L						18	-11	-68	1	7,42
Lingual Gyrus	R						19	16	-55	0	4,81
Precuneus	R	7	14	-52	41	4,96					
Precuneus	L						31	-13	-47	32	5,03
Cuneus	R						17	9	-80	11	4,90
Cuneus	L	23	-11	-72	9	5,63					
Fusiform Gyrus	R	20	40	-39	-13	4,20	20	41	-39	-14	4,45
Fusiform Gyrus	R	19	37	-70	-14	4,30	19	37	-68	-12	4,52
Fusiform Gyrus	L	37	-35	-38	-14	4,56	37	-37	-45	-12	5,15
Anterior Cingulate Gyrus							24	4	31	-5	5,65
Anterior Cingulate Gyrus		24	-1	29	1	4,57	24	-8	10	28	4,48
Posterior Cingulate Gyrus	R	30	-4	-43	21	5,12	23,31	-5	-38	23	5.18
Parahippocampal Gyrus	R	34	30	3	-16	5,59	30	18	-46	1	4,72
Parahippocampal Gyrus	R						34	13	-14	-18	4,45
Parahippocampal Gyrus	L	19	-38	-43	-3	5,67	19	-36	-45	-6	5,38
Parahippocampal Gyrus	L						30	-17	-46	-1	4,80
Insula	R						13	31	-32	22	5,63
Insula	L	13	-35	26	15	4,80	13	-45	-7	2	5,19
Amygdala	R							27	-1	-11	4,58
Amygdala	L	28	-24	5	-23	4,69		-29	-2	-17	4,41
Nucleus accumbens	L		-5	16	1	4,68					
Thalamus	R		16	-10	10	4,57		16	-8	12	4,80
Thalamus	L		-20	-27	4	6,30		-23	-23	3	8,22
Putamen	L		-20	-9	14	5,05					
Putamen	R		25	4	16	4,69		29	2	-2	4,59
Cerebellum			-7	-47	-16	6,19		4	-42	-10	6,10

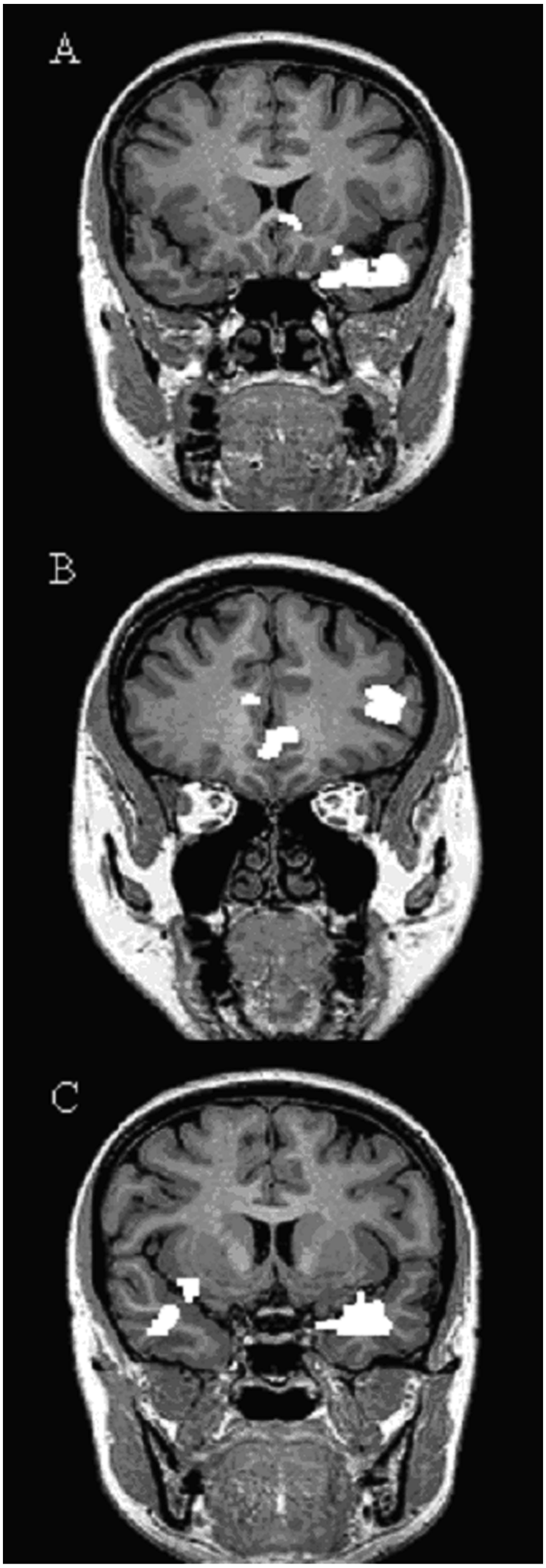

Figure 1. *(A) Relative increase in left nucleus accumbens and left amygdala during processing of positive pictures; (B) Relative increase in anterior cingulate and ventrolateral prefrontal cortex during processing of positive pictures; and (C) Relative bilateral increase in amygdala during processing of negative pictures*

control and patient groups. Afterwards, activations were studied based on clusters automatically defined (50 mm) by the software. Within each cluster of statistical significance, average t-test and significance value were determined. and their location was expressed in terms of gravitational x, y and z coordinates.

Results

Accuracy on task performance was 100% across conditions. Brain areas involved in processing of negative>neutral. and positive>neutral contrasts are reported in table 1. Inverse contrasts did not yield significant differences. As expected, a great degree of overlap exists between both contrasts between emotional and non-emotional pictures basically involving posterior activations in parietal and temporal cortex including the fusiform and parahippocampal gyrus.

As expected, both positive and negative pictures yielded significant activations in the amygdala (bilateral for negative pictures and lateralized on the left hemisphere for positive pictures). and in the lateral prefrontal cortex (Figure 1). Activations for negative pictures were more focus on dorsolateral prefrontal cortex (BA9 and 46) and premotor cortex (BA6), whereas activations for positive pictures were exclusively focused on the orbitofrontal and ventrolateral prefrontal cortex (BA47). Finally, the comparison positive and neutral pictures yielded activations on the left nucleus accumbens (Figure 1).

Discussion

The blocked design used in the present study has produced results similar to those reported using event-related designs (Simpson et al., 2000). Main activations due to the presence of pictures with emotional significance occurred in the occipital and temporal lobes, primarily in the fusiform and parahippocampal gyrus. Although the fusiform gyrus was proposed to be involved in the processing of faces (Kanwisher, McDermott, & Chun, 1997), it has been also suggested that this hyperactivation was directly due the processing of emotional stimuli (Simpson et al., 2000). In fact, recent data has indicated that processing of emotional faces also hyperactivated these areas when compared to neutral faces (Hariri, Tessitore, Mattay, Fera, & Weinberger, 2002).

Results have also confirmed previous studies relating the processing of emotional pictures to the lateral prefrontal. Some previous studies requiring emotional judgements of the pictures of the IAPS revealed main activations in the medial prefrontal cortex (Northoff et al., 2004). In the present study, however, the use of emotional pictures as background while performing a cognitive non-related task has produced main activations in lateral ventrolateral and dorsolateral prefrontal cortex. This discrepancy is consistent with a recent study showing that the use a cognitive task instead of an emotional judgment task was related to greater activations in lateral (an not medial) prefrontal cortex (Norhoff et al., 2004). In this sense, our block-design task partially confirmed previous results obtained with an event-related design.

Our findings have revealed a bilateral (left more than right) activation of amygdala for negative pictures and a left activation of amygdala for positive pictures. These results are in line with recent functional imaging studies of the human amygdala, which have shown that amygdala activation reflects the integration of perceptual information with emotional associations for the stimuli (Buchel et al., 1998; Phelps et al., 2001). and that such activation occurs even under passive viewing conditions (Breiter et al., 1996), as we used in the present study. There are some important outstanding issues regarding the role of the amygdala in processing emotional information, as during the emotional memory formation (Conejo et al., 2005). First, is there hemispheric asymmetry? Most functional imaging studies using emotional faces as stimuli have reported left amygdala activation. and Morris et al. (1998) showed differential activation of the right and left amygdala for subliminally and supraliminally presented stimuli, respectively. Present results were consistent with the above findings. Second, did the amygdala respond to positive as well as negative stimuli? Present study shows an activation of the left amygdala for positive stimuli that is consistent with several recent reports have found responses also to highly arousing like sexually explicit movies or pictures (Beauregard, Levesque, & Bourgouin, 2001; Ferretti et al., 2005; Hamann et al., 2004). These results are consistent with the role of the amygdala in processing salient stimuli.

Even though the overlap between brain areas involved in the processing of positive and negatives pictures, the positive pictures of the IAPS with erotic and sexual content has activated brain areas involved in reward including the nucleus accumbens and lateral prefrontal cortex. Recent studies have found activation in the nucleus accumbens when seeing funny cartoons (Mobbs, Greicius, Abdel-Azim, Menon, & Reiss, 2003; Moran, Wig, Adam, Janata, & Kelley, 2004), beautiful faces (Aharon et al., 2001) and during deliberation of selecting a risky response (Matthews, Simmons, Lane, & Paulus, 2004). As far as we know, this is the first report of activation of the nucleus accumbens using positive IAPS images. Several factors may have contributed to this important result. First, the use of block designs instead of event-related may improve the detection of brain areas involved in a determinate cognitive process (Huttel et al., 2004). Second, the selection of the content of positive IAPS pictures and the selection of males may contribute to homogenise experimental conditions.

In sum, the use of block designs plus a careful selection of positive emotional pictures has served to identify the brain areas involved in appetitive motivation.. This procedure may be useful to investigate brain areas involved in emotion in healthy and pathological populations.

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[1] Numbers of selected images:

Neutral Pictures: 2840,5531, 7009, 7175, 7186, 7190, 7233, 7510, 7820, 5532, 7010, 7025, 7039, 7150, 7170, 7211, 7185, 7830, 7351, 5533, 7020, 7036, 7038, 7100, 7187, 7235, 7217, 7500, 7207, 7034, 7490, 7080, 7095, 7550, 7560, 7705, 7900, 7950, 7041, 5534, 5900, 6150, 7000, 7006, 7037, 7050, 7130, 7285, 7700.

Negative Pictures: 1210, 2053, 2490, 3030, 3180, 3230, 3500, 6200, 6530, 7380, 1280, 2205, 2900, 3051, 6360, 3530, 3130, 6570, 6830, 9040, 1300, 2730, 9001, 3120, 6210, 6550, 3010, 9008, 6410, 9430, 1930, 2750, 3053, 3350, 6010, 6510, 9181, 9007, 9410, 9611, 6560, 3071, 3220, 3266, 3550, 6212, 2710, 6831, 9050, 9420.

Positive Pictures: 4004, 4235, 4320, 4641, 4650, 4664, 4680, 4681, 4750, 4002, 4606, 4800, 4142, 4601, 4652, 4610, 4611, 4640, 4290, 4659, 4300, 4631, 4672, 4150, 4690, 4700, 4141, 4676, 4180, 4660, 4232, 4653, 4001, 4609, 4683, 4310, 4651, 4210, 4656, 4607, 4658, 4005, 4608, 4250, 4810, 4603, 4220, 4670, 4599, 4003.

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