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Brief article

Recognizing one's own face

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Abstract

We report two studies of facial self-perception using individually tailored, standardized facial photographs of a group of volunteers and their partners. A computerized morphing procedure was used to merge each target face with an unknown control face. In the first set of experiments, a discrimination task revealed a delayed response time for the more extensively morphed self-face stimuli. In a second set of experiments, functional magnetic resonance imaging (fMRI) was used to measure brain activation while subjects viewed morphed versions of either their own or their partner's face, alternating in blocks with presentation of an unknown face. When subjects viewed themselves (minus activation for viewing an unknown face), increased blood oxygenation was detected in right limbic (hippocampal formation, insula, anterior cingulate), left prefrontal cortex and superior temporal cortex. In the partner (versus unknown) experiment, only the right insula was activated. We suggest that a neural network involving the right hemisphere in conjunction with left-sided associative and executive regions underlies the process of visual self-recognition. Together, this combination produces the unique experience of self-awareness. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

The face is our most characteristic external feature. Mirror recognition does not

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occur in humans before 18 months or in other primates, except adult great apes (Gallup, 1970; Parker, Mitchell, & Boccia, 1994). Several investigations have shown that the processing of self-relevant information differs from processing objective information. For example, in word recognition studies, self-referential encoding facilitates recall better than any other mnemonic strategy (Kihlstrom & Klein, 1997; Schacter, 1989). Listening to autobiographical episodes (Fink et al., 1996) or judging one's own personality traits (Kircher, Brammer, Simmons, Bartels, & David, 2000) has been shown to activate distinct cerebral areas. Specific operations underlying self-processing have been proposed (Schacter, 1989; Snodgrass & Thompson, 1997). In previous imaging studies, verbal material has been used to investigate semantic self-referential knowledge (Craik et al., 1999). However, a stronger and more direct cue for investigating self-information processing is one's own face, with which we are very familiar from mirror reflections and photographs. Understanding of how we recognize a familiar face has grown through experiments in cognitive psychology (Bruce & Young, 1986), neurophysiology (Seeck et al., 1993), neuroimaging (Haxby et al., 1996; Kapur, Friston, Young, Frith, & Frackowiak, 1995), and neuropsychological studies of patients with face recognition deficits (prosopagnosia) (Sergent & Poncet, 1990). Surprisingly, little research has been devoted to facial self-recognition, presumably because it is assumed that this cannot be separated from familiar face recognition. Some patients with severe prosopagnosia (Sergent & Poncet, 1990) and Alzheimer's disease (Bologna & Camp, 1997) fail to recognize themselves in the mirror yet no pure cases of 'autoprosopagnosia' have been described. In an event-related potential (ERP) study by Ninomiya, Onitsuka, Chen, Sato, and Tashiro (1998) a larger P300 response to the subject's own face compared to familiar faces has been reported.

One major problem when studying self-face processing is to control for emotional salience and overlearnedness, since both are known to influence processing (Klatzky & Forrest, 1984; Phillips et al., 1997; Valentine & Bruce, 1986; Young, Hay, McWeeny, Flude, & Ellis, 1985). In our study, we tried to overcome this by using the face of each subject's partner for comparison. We used morphed versions of the subject's own face and their partner's face, each blended with an unknown, same sex identity, and conducted two sets of experiments. In the first set, we measured reaction time and categorical boundaries for recognition of the subject's own face and their partner's face. In the second set, we measured cerebral activation with fMRI while subjects viewed the same stimuli. We predicted a specific behavioural and neural response when subjects viewed their own face because of its outstanding subjective importance.

2. Materials and methods

2.1. Reaction time experiments

2.1.1. Subjects

Twenty healthy, male volunteers participated in the behavioural study (mean age

31 years, mean IQ estimate 113; National Adult Reading Test, Nelson & Willison, 1991). Exclusion criteria were history of brain injury, and past and current psychiatric or neurological illness. No subject was taking regular medication. Neither the subjects nor their female partners wore spectacles and none had facial hair. Subjects had known their partners for between 1 and 16 years (median 2.7).

2.1.2. Stimuli

Coloured, full face, frontal view photographs were taken of the 20 participants and their partners in a photo studio under standardized conditions. The partner's face was chosen as an emotionally salient and highly overlearned non-self face. A similar-looking novel face (identity unknown to participants) matched for age and sex was paired with each of the self and partner faces. All the photos were digitized; the subjects' faces were then mirror transposed and a black template was applied semiautomatically to remove non-facial attributes such as background, hair and ears. The individual faces were manipulated ('morphed') using a computer warping package with their assigned identities in 5% steps (Benson, 1994), resulting in graded blending of facial features between two same sex identities. The purpose of this was to have a number of representations of an individual's face which were sufficiently novel to prevent habituation, yet were easily recognizable.

2.1.3. Experimental design

Subjects were initially familiarized with the endpoint of the morph series, i.e. the real identities, once for 15 s. Subjects were then presented with the morphed images along the dimensions self versus unknown and partner versus unknown. The 21 faces of one morph series were presented on a computer screen, one image at a time, in a randomized order and again serially, starting from each endpoint (presentation order: 'known' first and 'unknown' first). The repeated use of versions of the same novel face controlled for familiarity. Each series (presentation order: 'random', 'known', 'unknown') was presented with a short pause between each run, twice per subject in a pseudorandom order. The subjects had to indicate whether or not the face was known to them (self, partner) by pressing one of two buttons with the right or left index finger. The subjects were given the instruction: 'If the face on the screen looks more like you (partner), press the right button with your right index finger, if the face looks more like the other person, press the left button with the left index finger.' The image was displayed until a button was pressed; after a 1 s interval with the screen blank, a fixation point appeared in the centre of the screen and the next face was shown.

2.2. fMRI experiments

Six weeks after the behavioural study, a subgroup of six subjects (mean age 31 years, mean IQ estimate 115) participated in two 5 min fMRI experiments for presentation of the self versus novel and partner versus novel face series. The seven faces closest to the overlearned endpoint (100–70% self or partner) in each series were presented one at a time on a computer screen in a randomized order for 2

s, each followed by a 1 s blank screen. This was followed by presentation of seven faces from the unknown endpoint (non-self, non-partner) in a similar manner. As distracters, two faces of the opposite end of the morph spectrum were randomly intermingled into each block to ensure that subjects attended. Stimuli were presented 3.5 m from the subject, subtending visual angles of 10° horizontally and 8° vertically. Each experiment consisted of ten separate 30 s presentation phases, alternating between overlearned (phase A) and novel (phase B) stimuli, with the first presentation being 'overlearned'. In the 'B' phase of both experiments repeated morphed versions of a novel identity's face were employed. Therefore, this face soon became familiar and hence, in addition to processing of facial configurations per se, familiarity was controlled for across both phases of both experiments. The presentation order of the two experiments was counterbalanced across subjects. Subjects indicated whether the identity was overlearned (self or partner) or novel by pressing one of two buttons with the right thumb as quickly and accurately as possible. To familiarize subjects with the stimuli, they viewed the endpoints of each morphed series for 15 s in the scanner. Prior to MRI data acquisition, subjects were presented with six faces as a practice block.

2.2.1. Image acquisition and analysis

Functional MRI data were acquired using a GE Signa 1.5 T system (General Electric, Milwaukee, WI, USA) with an ANMR operating console and hardware (Advanced Nuclear Magnetic Resonance, Woburn, MA, USA) for gradient echoplanar imaging (EPI) at the Maudsley Hospital, London. One hundred T2*-weighted images depicting BOLD contrast were acquired at each of 14 non-contiguous near axial planes (7 mm thick with 0.7 mm slice skip; in-plane resolution 3 mm) parallel to the intercommissural (AC-PC) line: TE = 40 ms, TR = 3 s, flip angle 90°, number of signal averages 1. At the same session, a 43 slice, high resolution inversion recovery echoplanar image of the whole brain was acquired in the AC-PC plane with TE = 73 ms, TI = 180 ms, TR = 16000 ms, in-plane resolution 1.5 mm, slice thickness 3 mm, slice gap 0.3 mm. Rigid body motion in 3D was estimated and corrected by realignment and regression (Brammer et al., 1997). Periodic change in MR signal intensity at the frequency of alternation between A and B tasks was estimated by fitting a sinusoidal regression model to the fMRI time series observed at each voxel. The model included sine and cosine waves at the frequency of the experimental input function, with amplitudes γ and δ , respectively. The standardized power of response at experimentally determined frequency was estimated by $P = (\gamma^2 + \delta^2)$ divided by its standard error. The sign of γ identified the timing of maximum MR signal with respect to the input function: if $\gamma > 0$, the maximum signal was observed in the first condition; if $\gamma < 0$, the maximum signal was observed in the second condition. Parametric maps representing P and γ at each intracerebral voxel were constructed. To sample the distribution of P under the null hypothesis that observed values of P were not determined by experimental design, the 99 images observed in each plane were randomly permuted and P was estimated as above in each permuted time series. This process was repeated ten times, resulting in ten permutated power maps at each plane for each subject. Observed and permuted power maps were transformed into the standard space of Talairach and Tournoux (1988) as previously described (Brammer et al., 1997), and smoothed by a 2D Gaussian filter with full width at half maximum of 14.4 mm. The median observed power at each intracerebral voxel in standard space was tested against a critical value of the permutation distribution for median power ascertained from the permuted power maps. For a one-tailed test of size $\alpha = 0.001$, the critical value was the $100(1 - \alpha)$ th percentile value of the permutation distribution. Voxels for which observed median power exceeded this critical value were considered activated and coloured according to the sign of median γ . Activated voxels with median $\gamma > 0$ were coloured red and superimposed on a grey scale EPI template image to form a generic brain activation map (GBAM) (Brammer et al., 1997).

We used repeated measures analysis of variance to estimate task-related differences in the power of functional response at each voxel. The main effect of task was tested for significance by permutation at voxels which demonstrated significant activation by one task or both (Bullmore et al., 1999; Edington, 1980).

3. Results

3.1. Behavioural experiments

We performed an analysis of the perceived categorical boundaries for each subject in each trial. When the responses for each trial are sorted from image 1 to 21, the categorical boundary is defined as the mean between the first image judged as 'unknown' and the image after the last image judged as 'known'. In both the self/ unknown and the partner/unknown conditions, subjects judged stimuli as belonging to distinct categories with a sharp boundary between them (see Fig. 1). A regression of categorical boundary was performed on the 'order of presentation' and 'identity' again with a random effect for subject. There was a significant effect for 'order of presentation' (P < 0.001) but not for 'identity', and no 'order' × 'identity' interaction. That is to say that the categorical boundary of the target identity (opposite from the starting point) regardless of 'self' or 'partner' or the order of the serial presentation occurred sooner than in the random presentation.

For the analysis of response times, we subdivided the morph series into different blocks. This was done to test for the effect of the morphing process. Four blocks of each of the series in each experiment were formed and compared: face 1 (over-learned: self/partner) versus face 21 (novel), faces 1–3 versus faces 19–21, faces 1–7 versus faces 15–21 and faces 4–7 versus faces 15–18. A further division of faces 8–10 versus faces 12–14 was not carried out because of a high variability in the identity judgement across the subjects in this area. Because the data were skewed, a logarithmic transformation of the data was performed prior to analysis. The difference between the mean reaction times for the self/partner faces and the novel faces (1 versus 21, 1–3 versus 19–21, 1–7 versus 15–21, 4–7 versus 15–18) was regressed on a dummy variable for partner versus self and two dummy variables for order of presentation (reference presentation order: 'known' first), with a random effect for



Fig. 1. Data from the behavioural experiment. The graph shows the results from the categorization analysis. On the *x*-axis, image 1 represents either the subject's own (self) or their partner's face (partner) morphed in 20 steps with an unknown identity (number 21) of the same sex. The *y*-axis depicts the percentage of subjects judging a given (or lower numbered) image as unknown. The graphs represent the presentation order (PO). PO "known" represents the serial presentation starting from face 1 to 21, PO "unknown" represents from face 21 to 1 and PO "random" represents the random order.

subject to take account of the repeated measures design. Four regression analyses were carried out, one for each type of difference. Three significance tests were carried out for each regression. Test (1) was for a difference in reaction time between the overlearned and novel faces when looking at one's own face ('self') in the presentation order 'known' first. We found significant reaction time differences for face 1 versus face 21 (P = 0.001), faces 1–3 versus faces 19–21 (P < 0.001), faces 1–7 versus faces 15–21 (P < 0.001) and faces 4–7 versus faces 15–18 (P < 0.001). In Test (2) we looked for the effect of presentation order. Significant results were present for face 1 versus faces 15–21 (P = 0.001), faces 1–3 versus faces 19–21 (P < 0.001), faces 1–7 versus faces 15–21 (P = 0.001), faces 1–3 versus faces 15–18 (P < 0.001), faces 1–7 versus faces 15–21 (P = 0.001), faces 1–3 versus faces 15–18 (P < 0.001), faces 1–7 versus faces 15–21 (P = 0.001), faces 1–3 versus faces 15–18 (P < 0.001). In Test (3) there was no difference in the effect of partner versus self.

We tested direct differences in reaction times of the overlearned spectrum of the morphs between self and partner across the grouped morphing blocks using a random effects model. We only found significant differences in reaction time between 'self' and 'partner' for faces 4–7 (P = 0.01) in the presentation order 'known' first (Table 1).

In summary, we did not find major differences in the processing between one's own face and the partner's face.

	Face 1 (overlearned)	Face 21 (novel)	Faces 1–3 (overlearned)	Faces 19–21 (novel)	Faces 1–7 (overlearned)	Faces 15–21 (novel)	Faces 4–7 (overlearned)	Faces 15–18 (novel)
Experiment 1: order of presentation, 'known' (from face 1 to 21) Self Partner Significance	4039 (13348) 686 (284) NS	589 (345) 383 (224)	1821 (4552) 602 (254) NS	584 (294) 415 (228)	1240 (2003) 630 (294) NS	576 (271) 433 (218)	805 (381) 651 (359) 0.01	571 (263) 447 (214)
Experiment 2: order of presentation, 'unknown' (from face 21 to 1) Self Partner Significance	513 (321) 449 (293) NS	928 (724) 696 (309)	524 (345) 446 (244) NS	632 (299) 616 (389)	554 (330) 459 (237) NS	574 (252) 549 (211)	577 (355) 469 (245) NS	532 (308) 500 (223)
Experiment 3: order of presentation, random Self Partner Significance	551 (286) 487 (89) NS	620 (268) 580 (147)	554 (201) 498 (123) NS	571 (216) 533 (110)	614 (209) 563 (113) NS	589 (207) 551 (130)	660 (246) 612 (129) NS	603 (203) 564 (153)

Table 1 Differences in response time in relation to the morphing process^a

^a Faces were morphed in 5% increments from the identities No. 1 (self or partner) to No. 21 (novel male or female). Original reaction times (ms) are given as the mean (SD).

3.2. fMRI experiments

3.2.1. Individual analysis of 'own face' and 'partner's face' experiments

Accuracy of identity judgement for both the self and the partner experiment was 99.2% (98.3–100%, SD 0.6%). Reaction time data recorded during the scanning procedure showed no significant differences between the two experiments when responses were compared for the two overlearned faces (self: 1069 ms, SD 100 ms; partner: 1092 ms, SD 97 ms; P = 0.8).

The fMRI data revealed a marked difference in activation for the self compared with the partner experiment (see Table 2). In the self versus novel condition, a large cortical and sub-cortical network was revealed. This included right limbic areas: hippocampal formation (Brodman area, BA 27/30), insula, anterior cingulate (BA 24/32), as well as left superior temporal (BA 42), left inferior parietal (BA 40) and left prefrontal cortex (BA 8/9 and 45/46; Fig. 2 row A). In contrast, there was relatively little activation in the partner versus novel condition which was confined to the right anterior insula (Fig. 2, row B).

Table 2

Areas of significant activation during recognition of own (minus unknown) and partner's (minus unknown) face

Cerebral region	Brodman's area	Side	x	у	z	No. activated voxels
fMRI experiment 1: self versus novel						
Anterior and mid-posterior insula	-	R	49	- 3	4	50
	-	R	46	- 3	- 2	23
Hippocampal formation	27/30	R	11	- 45	4	7
		R	12	- 36	- 2	6
Anterior cingulate	24/32	R	3	36	4	12
		R	6	42	- 2	8
			0	6	37	14
Precuneus	31	R	6	- 64	20	9
		R	9	- 61	26	8
Inferior frontal gyrus/DLPFC	45/46	L	- 38	31	4	11
		L	- 32	31	20	18
Middle frontal gyrus	8/9	L	- 26	31	37	9
Superior temporal gyrus	42	L	- 43	- 14	9	16
Supramarginal gyrus/inferior parietal lobe	40	L	- 49	- 42	31	11
Lenticular/subthalamic nucleus	_	R	12	- 11	- 2	23
Cerebellum	_	R	9	- 47	-18	18
Fusiform gyrus		L	- 20	- 83	- 13	34
fMRI experiment 2: partner versus novel						
Anterior insula	-	R	26	14	15	5



Fig. 2. Generic brain activation mapping in six right-handed normal subjects during perception of faces depicting themselves (minus unknown identity; row A) and their partner (minus unknown identity; row B). Row C shows the significant differences in activation (P < 0.05) between the two experiments. The activations were superimposed on a template warped into Talairach space. The numbers below the slices indicate *z*-axis Talairach co-ordinates.

3.2.2. Differences in activation between 'own face' (fMRI experiment 1) and 'partner's face' (fMRI experiment 2)

We tested the statistical differences in activation between the 'own face' and 'partner's face' fMRI experiments formally.

The null hypothesis was tested with the probability of Type I error for each test (P = 0.05). For this size of test, no more than 25 false positive voxels are expected over the search volume under the null hypothesis. There were 148 suprathreshold voxels. All the voxels with significantly different fundamental power quotient values (Table 3 and Fig. 2, row C) originated from the own face experiment. These were located in the right insula, hippocampal formation (BA 27/30), lenticular/subthalamic nucleus, middle temporal gyrus (BA 21), and the left-sided inferior frontal gyrus (BA 45/46), middle frontal gyrus (BA 8/9), supramarginal gyrus/inferior parietal lobe (BA 40), cerebellum and lingual gyrus (BA 18).

4. Discussion

In two independent sets of experiments, we investigated processing of two highly overlearned faces, one's own and one's partner's, on a behavioural and neural systems level. We found a reaction time advantage for the recognition of morphs of overlearned faces compared with strangers' faces. The morphing procedure as well as the order of presentation influenced the response times significantly. Facial identity appears to be perceived categorically. There was no difference in categorical boundaries for self/novel and partner/novel. In summary, one's own face is not processed differently on a behavioural level when compared with another over-learned, emotionally salient face, the partner's. In two fMRI experiments, we demonstrated that recognition of the own face activated right limbic and left prefrontal regions, whereas recognition of the partner involved only the right insula.

In a related study to ours, Beale and Keil (1995) compared the recognition of famous and novel morphed identities. They found a reaction time advantage for the famous faces. A higher processing speed for familiar faces (self or famous), whether morphed or unmorphed (Keenan et al., 1999; Klatzky & Forrest, 1984; Tong & Nakayama, 1999; Valentine & Bruce, 1986; Young et al., 1985), was replicated in our study, where the response time was faster for the overlearned faces. The faster recognition of famous or overlearned identities could be attributed to face processing models, in which the face recognition units and person identity nodes process information from very familiar (overlearned) faces more quickly than that from less familiar ones (Bruce & Young, 1986) because of ease of access to stored representation and semantic information, respectively. We extended the findings of Beale and Keil (1995) and showed that categorical perception of faces occurs also between overlearned and recently familiarized faces. Another finding is the fact that categorical boundaries depend on the order of presentation of the morphs. The boundaries are shifted towards the identity the serial presentation started with. This presumably reflects a response bias whereby subjects 'anticipate' the boundary.

Comparing the response time of the two highly overlearned faces, self and partner, directly in a post-hoc analysis, we found a small but significantly slower proces-

Table 3

Cerebral region	BA	Side	Tal. <i>x</i> ^a	Tal. y	Tal. z	No. of activated voxels ^b
Fusiform gyrus	_	L	- 14	- 81	- 13	29
Lenticular/subthalamic nucleus	_	R	12	- 11	- 2	17
Middle temporal gyrus	21	R	46	- 3	- 7	16
Anterior and mid-posterior insula	-	R	40	- 3	4	10
	_	R	52	- 6	- 2	8
Inferior frontal gyrus	45	L	- 38	25	20	6
Supramarginal gyrus/inferior parietal lobe	40	L	- 49	- 39	31	6
Hippocampal formation	30	R	9	- 36	- 2	4

Cerebral regions showing significantly different power of response between experiment 1 ('own face') and experiment 2 ('partner's face') (response: own face > partner's face)

^a Talairach co-ordinates (mm) refer to the voxel with the maximum FPQ (fundamental power quotient) in each regional cluster.

^b The probability of false activation of each voxel in the generic brain map over all six subjects was <0.05.

sing speed for the self faces when they were morphed more (faces 4–7), but not when morphed less extensively (faces 1–3). The effect is subtle, since it was not present in the multiple regression analysis and it was found in the serial presentation (order 'known' first) but neither in the random presentation nor in the fMRI experiments, in which randomized presentation order was also employed. The combination of serial presentation and strong morphing produces a delayed recognition for the self compared with the partner's face. We can speculate that the delayed recognition effect might be due to a mismatch of the internal representation of the self face and reality. For example, many people think that a snapshot of themselves is not an accurate representation. The morphing procedure might exaggerate the mismatch between self-representation and photograph even further, resulting in a more complex verification process, which leads to a longer response time.

Previous PET and fMRI studies have investigated cerebral areas engaged in recognition memory of faces (Grady et al., 1995; Gur et al., 1997; Haxby et al., 1996; Kapur et al., 1995; Sergent, Ohta, & MacDonald, 1992). In these studies subjects had to acquire new information just before or while being scanned. In newer related studies, recognition of a number of different famous or unfamiliar faces (George et al., 1999) or objects (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999) was compared. We were not interested in mere familiarity but rather selfrecognition or awareness. We matched the self face with the partner's face in order to control for emotional salience and overlearnedness (familiarity). It is assumed that subjects see their own face and their partner's face on a daily basis. The subjects were also extensively familiarized with all the stimulus material 6 weeks prior to, and through repeated presentations, during scanning. The activation consequent upon recognizing one's own face was more extensive and the pattern was striking. The right limbic regions, which were extensively activated when self was contrasted with novel, are known to be engaged in pleasant and unpleasant emotional responses (Lane et al., 1997; Phillips et al., 1997). A study of autobiographical memory has shown the engagement of right limbic regions in the recollection of personal memories (Fink et al., 1996). Preilowski (1979) measured skin conductance in split-brain patients and healthy subjects while faces of themselves, faces of persons they knew well, emotional scenes and objects were presented to one hemifield for 100 ms. The number of galvanic skin responses was higher to the own face presented to the right hemisphere than to any other stimulus-visual field combination in both groups. We interpret the activation of the right limbic system in our study as a unique, strong emotional response to seeing our own face. This emotional response seems to be present both for morphed, as in our experiment, and for unmorphed faces (Preilowski, 1979). The left prefrontal cortex, which was only activated by self faces, is thought to have an important role in executive processes such as the integration of information to form a coherent 'whole' from multi-modal inputs (Miller, 1992; Vandenberghe, Price, Wise, Josephs, & Frackowiak, 1996).

In response to the partner's face, the activation of the anterior insula, about 1 cm above the activation site in the self condition, could reflect an emotional response to the both intimate and familiar partner's face. We assume that the gender of the subject's partner did not bias the results, since in both face experiments we used same sex control faces. A sex bias (i.e. males viewing female faces) should therefore have been cancelled out. Replication of the study with other intimately known individuals (e.g. siblings and women viewing male faces) would nonetheless be desirable.

One explanation for the differences in activation between the two fMRI experiments is that memory and verification processes are being stimulated in the self condition only rather than processes inherent in self-recognition. This is unlikely given the closeness of the matching within each experiment and the employment of an initially unknown, but recently familiar face as the control condition in both, hence the minimal activation in the partner versus novel face experiment. Furthermore, there was little difference found between self and partner in the reaction times or categorical boundaries in the behavioural experiment. Nevertheless, we are unaccustomed to picking out our own face from a range of possible faces, unlike the more frequent task of identifying a well known person's face in a crowd. A component of the activation may therefore reflect such novelty and the additional attentional deployment. Finally, the differences in activation between the self and partner experiments may have been exaggerated by the morphing procedure, that is, morphing may have interacted with self-recognition in some way to engage attention, for example. However, even if this were the case, the presence or absence of selfrelevant information is the crucial factor distinguishing the two experiments and not the morphing procedure.

The combination of right limbic and left cortical activation could underlie human self-recognition. We suggest that it is this limbic-cortical connection which enables the integration of affect and cognition. Experiments with split-brain patients (Gallois, Ovelacq, Hautecoeur, & Dereux, 1988; Preilowski, 1979; Sperry, Zaidel & Zaidel, 1979) have shown that although rudimentary self-recognition occurs in the disconnected right hemisphere, only transcallosal transfer of information enables the sensory experience to reach awareness. The onset of self-recognition in human infancy correlates with the myelination of fibres in the frontal lobe (Kinney, Brody, Kloman, & Gilles, 1988). Isolated failures of self-recognition have yet to emerge in the neurological literature. Such failure does not seem to occur following isolated frontal lesions or in cases of amnesia with profound loss of autobiographical memory (Tulving, 1993) where there is a preservation in the sense of self. The relatively widespread and bilateral activation we have demonstrated in response to the self stimuli suggests that many processes contribute to self-perception with some built-in redundancy, hence the resistance to disruption by common neurological lesions.

5. Conclusion

We have reported evidence of a distinct neural substrate underlying facial selfrecognition involving the right limbic system and left prefrontal and temporo-parietal cortex. One's own face is a stimulus that activates unique self-referential processing. We suggest that the interplay of both emotional and associative cognitive processes is necessary for the unique perception of a coherent self. Further studies are needed to clarify the specific nature of the neural correlates of visual selfrecognition.

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