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The role of the IPL in person identification

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ABSTRACT

We investigate the brain activations when identifying a newly encountered individual as being the same as a person previously perceived, a fundamental but seldom acknowledged process. In an identity condition, two faces had to be identified as the same person in contrast to a control condition, in which two faces had to be recognised as belonging to similar looking twins. Our results demonstrate an increase of neural activation in frontal as well as in parietal areas including the left inferior parietal lobe and the precuneus during identification. We introduce mental files theory to model this process as a linking of co-referential files and identify important connections to other domains in neurological and cognitive science (e.g., delusional misidentification syndromes, theory of mind).

1. Introduction

The human mind does not only recognise individuals and objects that we encounter but also identify[1] things as being the same entity that has been encountered previously. Recognising someone, e.g., an old friend, involves both the processing of feelings of familiarity and the recollection of specific features in context. These two components form the basis for the standard dual process model of recognition (Aggleton and Brown, 2006; Diana et al., 2007; Yonelinas, 2002; Yonelinas et al., 2010). On this standard model, recognising someone as the same individual encountered previously involves reactivation of an individual specific representation together with an episodic memory of the previous encounter (Fields, 2012). We can think of this individual specific representation in terms of a 'mental file' (Recanati, 2012).

A mental file is created upon an encounter with an individual—the file's referent. The file's function is to track its referent over time, collect, and store information about it. When the individual is re-encountered at a later time, the file will be re-activated, and its content can be updated by adding new information about the individual. This file retrieval process performs correctly if the same mental file is retrieved for the individual for which the file was created. The process performs incorrectly when a mental file for another individual is retrieved for which the file was not created, regardless of how many detectable features both individuals share (e.g., identically looking objects, monozygotic twins). Correct re-activation of a mental file of an individual makes for immediate recognition of that individual.

The process of immediate recognition has been investigated with models of familiar face recognition (, e.g., Haxby et al., 2000; Gobbini and Haxby, 2007). Familiar face recognition relies on a set of distributed brain regions that include a core system for analysing the visual appearance of faces and an extended system for the spontaneous retrieval of person knowledge. However, research in cognitive sciences has shown that current face recognition models are incomplete because the perceptual system does not have the expressive power to represent identity as it cannot differentiate between multiple instances of the same entity and different but similar entities (Bullot, 2014; Bullot and Rysiew, 2007).

Representing identity becomes necessary when immediate recognition fails because the relevant file for the known individual is not being retrieved. In this case a new mental file has to be deployed for the same individual. One file represents it as the known individual, the other as a newly encountered individual. This amounts to a mistake, a failure to identify, precisely because these two represented individuals are in fact one and the same. In other words, unbeknownst to the subject, the two files are de facto[2] co-referential. Identification of the individual then requires an identity judgment, i.e., the two files have to be linked, which establishes the identity of their referent.

The process of linking co-referential files is not domain specific for

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[1] The term person identification denotes the deliberate and conscious process of recognising an individual's identity that has been known or encountered before under a different conception. It is an identity judgment.

[2] *De facto* is used here to indicate that two files *actually* refer to the same individual, even though the subject is not aware of this fact.

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identifying persons. Linking of files denotes the process of recognising that two thoughts (representations) are about the same thing. It forms a cognitive basis for judgements of identity (Recanati, 2014). Explicit identity judgments are not only present in identification but also in meta-representational tasks that require to represent multiple representations of the same thing or the same individual, e.g., in co-referential language processing, in understanding of mental perspectives, or in the retrieval of autobiographical memory. In the following section, we will review studies from these different domains to highlight the role of co-referential linking and its neuronal basis in cognition. More specifically, we conjecture on the basis of suggestive evidence that co-referential linking is associated with activity in the left inferior parietal lobe and the precuneus.

In discourse comprehension, co-referential file linking is needed when the identity of an individual has to be established explicitly. For instance, when given the sentence, ‘Ronald told Frank that he had a positive attitude towards life’ the reader cannot resolve the ambiguous anaphoric reference, i.e., whether the pronoun “he” refers to Ronald or to Frank (Nieuwland et al., 2007). Hence, the reader has to temporarily represent a third person and represent that this person is either identical to Ronald or to Frank and hope that the reference can be resolved later. This process is similar to the case of identification. When immediate recognition of an individual has failed, the subject may transiently think of two people (entertain two mental representations). The thinker has to judge that this person is (identical to) the individual previously encountered and represent this identity by linking the two representations. Similarly in the case of ambiguous pronouns, one has to represent that the person referred to by ‘he’ is identical to either Ronald or Frank.

More direct neuronal evidence for representing identity is provided by a recent study using identity statements (Arora et al., 2015). When reading about the bus driver and the tour guide one naturally thinks of two people on the tour bus. The ensuing identity statement, ‘the driver is the tour guide’ makes one realise that there is but one person, i.e., one has to represent the identity of the driver and the tour guide. In this study, the left inferior parietal lobe and the precuneus were specifically engaged by processing the identity statement (Arora et al., 2015). Both areas also contribute to ambiguous co-referential processing along with the medial frontal cortex and the right temporoparietal junction (Nieuwland et al., 2007).

The left inferior parietal lobe/temporoparietal junction also plays a critical role in understanding mental perspectives. This area is commonly activated as part of the mentalizing network when people infer and reason about beliefs, desires, and intentions. This mentalizing network is based on the medial prefrontal cortex, the precuneus and the bilateral temporoparietal junction (Schurz et al., 2014). Lesion studies indicate that the left inferior parietal lobe/posterior temporoparietal junction might be necessary for theory of mind as damages to this area caused specific deficits in mental state attribution (Apperly et al., 2004; Biervoye et al., 2016; Samson et al., 2004). Mental files theory provides an explanation for these results as theory of mind requires linking of co-referential files. In the case of theory of mind, it is assumed that we form co-referential ‘vicarious files’ to capture people's beliefs and perspectives about objects (Perner and Brandl, 2005; Recanati, 2012).

For instance, to use a false belief story for children, when Mistaken Max does not witness the transfer of his chocolate to a new location, he believes that the chocolate is still in its old location (Wimmer and Perner, 1983). To capture Max's mental state a vicarious chocolate file (indexed to Max) is created co-referential with one's regular chocolate file (Recanati, 2012). All events about the chocolate are recorded in the regular file, whereas on the vicarious file only those events that Max witnesses, i.e., the transfer to the new location is missing. So at the end of the story, the vicarious file shows the chocolate still in its old place, which provides the cognitive basis for knowing that Max believes it is still in its old place. Awareness that Max's belief is about the same chocolate as represented by one's regular file is provided by linking the two files. This is akin to linking the representation (file) of a known individual with the file for the currently perceived individual for identification.

Linking of co-referential files is also embedded in other processes, e.g., retrieval of episodic memories and autobiographical thoughts. Episodic memory retrieval is based on two independent processes: recollection and familiarity (Rugg and Yonelinas, 2003; Vilberg and Rugg, 2008). When an item from the learning set is recollected, it has to be judged as identical to the test item. In this case, a mental file for the item deployed at learning has to be linked with the mental file deployed at test. This is not required when the test response is based on a feeling of familiarity with the test item. Meta-analyses comparing recollection to familiarity localize recollection in medial-temporal, prefrontal, and parietal regions including the left inferior parietal lobe and the precuneus (Arora et al., 2015; Spaniol et al., 2009). Results of task-related fMRI, resting state functional connectivity and fMRI meta-analyses showed multiple convergence areas in the brain and a direct neural overlap including the left inferior parietal lobe/temporoparietal junction and the posterior cingulate/precuneus for episodic memory retrieval, autobiographical memory and theory of mind (Andrews-Hanna et al., 2014; Spreng, & Mar 2012). This is in line with our hypothesis that linking of co-referential files might be associated with activity in the left inferior parietal lobe and the precuneus.

In the present study, we investigated the process of identifying someone as being the same individual encountered in a previous episode. Participants were shown triads of photos of faces that varied in similarity (see Fig. 1). On the critical trials, two of the pictures showed highly similar faces. On some trials (identity condition) the two photos were meant to show the same person on two different occasions signalled by, e.g., the same neckline of their T-shirt. On other trials (twin condition) the two photos had to be interpreted as showing twins when their necklines were different. Since the physical appearance of the two faces was the same in both conditions, we excluded the possibility that subjects immediately recognised the faces by automatically retrieving the original files. Therefore, subjects had to create a new file when encountering a face that is highly similar to a face that has been seen before. In the identity condition subjects had to perform an identity judgment by linking the two files. In the twin condition the newly created file was not to be linked to the other mental file even though their visual content was the same as in the identity condition.

Existing studies looking at co-referential linking in different domains (Apperly et al., 2004; Arora et al., 2015; Biervoye et al., 2016; Nieuwland et al., 2007; Samson et al., 2004) consistently reported a significant role for the left inferior parietal lobe and the precuneus. We, therefore, predict that these areas will also be activated when identifying a person. While prior cognitive and neuroscientific research has investigated recognition without distinguishing immediate recognition from identification (Haxby et al., 2000; Gobbini and Haxby, 2007), the process of identifying someone as being the very same individual encountered on previous occasions has only been a subject in theoretical cognitive science and the philosophical literature (Bullot, 2014; Bullot and Rysiew, 2007; Fields, 2012; Recanati, 2012; Rips et al., 2006). By introducing mental files theory into neurocognition, we aim to extend the standard model of recognition by highlighting the importance of recognising the identity of individuals in addition to recognising the sameness of stimuli. Mental files help explain the cognitive process and to investigate the neurofunctional implementation of identification.

2. Methods

2.1. Subjects

Twenty-seven right-handed subjects (14 female) participated in the study. All of them were native German speakers, aged between 19 and 30 years (M = 23.11, SD = 2.67), with a normal or corrected-to-normal vision and no history of neurological disease. They gave informed

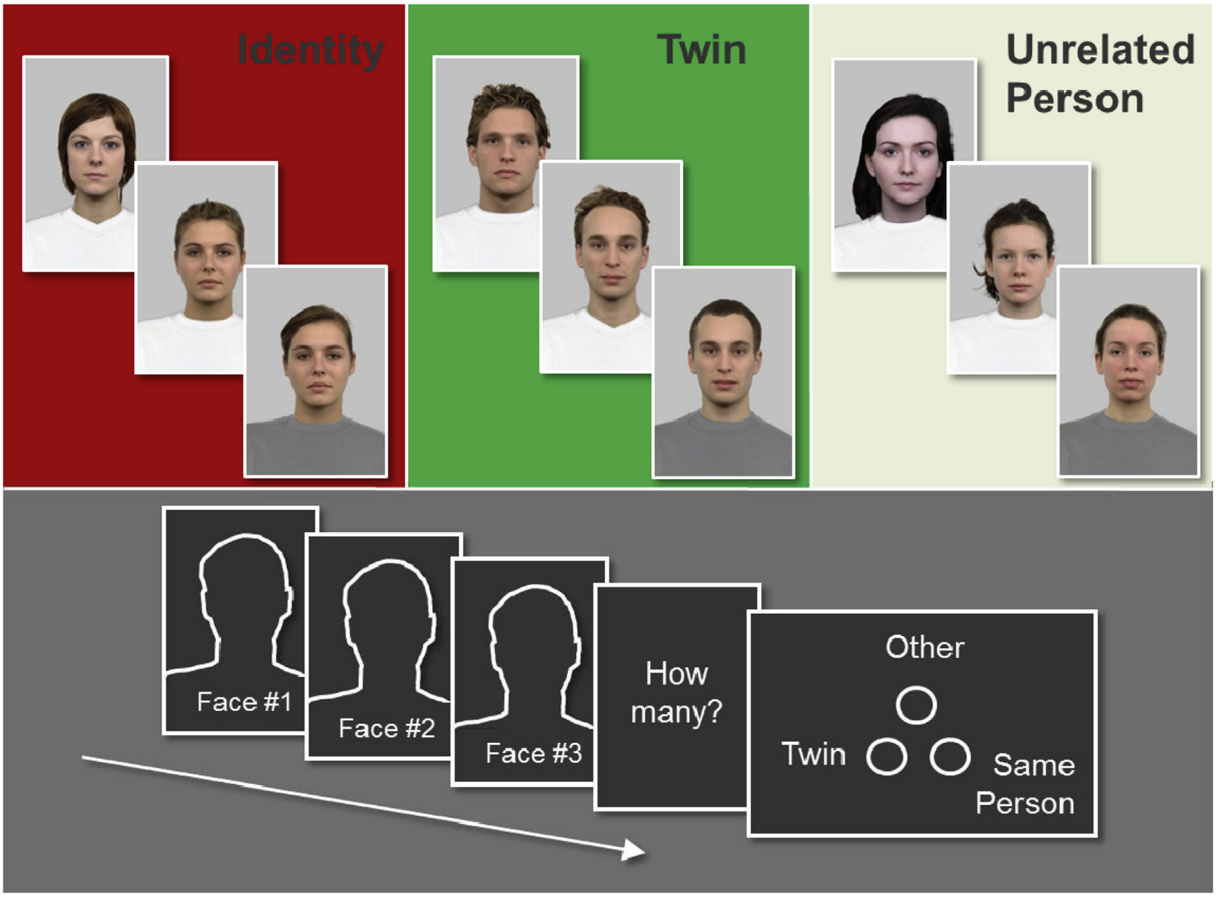

Fig. 1. Study Design. The experiment consisted of three different conditions: identity, twin, and unrelated person. Each condition showed a triad of photos of persons wearing either a white or grey shirt with a round or V-shaped neckline. The pictures in the identity and twin condition contained two similar faces (see second and third picture in the identity and twin condition). In the unrelated person condition, none of the three faces were noticeably similar. Participants used a cue (type of neckline) to decide whether a similar face belongs to the same person or to a twin. In this example, the same shape of neckline (round) indicates the same person, different shapes of neckline (V-shaped, round) indicate twins. After the triad, participants were asked to answer 'How many people own a white T-shirt?' and whether the two similar faces belonged to the same person, to twins or whether there were no similar faces (other).

consent before scanning and were given course credit for participation. All methods conform to the Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.2. Stimuli

Stimulus material was constructed from the Radboud Face Database (RaFD) (Langner et al., 2010) and the Psychological Image Collection (PICS) (http://pics.psych.stir.ac.uk/), showing front-view, colored images of faces with neutral expressions. Pairs of images were randomly matched according to gender. These pairs were used to create two morphed faces (doppelgangers) by selecting two images along the morphing continuum (40% and 60%). The hair on the faces was left unchanged to the originals. All images had a grey background and varied according to the condition in the color of their T-Shirt (white/grey) or shape of the shirt's neckline (round/V-shaped). For image manipulation, we used Abrasoft Fantamorph 5.4.6. and Adobe Photoshop CS6.

2.3. Rating and piloting

A first sample of 12 participants rated 100 doppelganger pairs how well these can be seen as twins as well as the same person. We chose the 18 pairs with the highest sum of the two ratings for the experiment, which ensured that these pairs were optimal for being used as similar looking twins as well as showing the same person on different occasions. The results show that these pictures were judged in equal parts as representing twins as well as the same person. From the remaining stimulus material, we selected 72 single images that served for the unrelated person condition and the presentation of a third face during the identity and twin condition. A second sample of 18 participants performed a self-paced behavioral version of the experiment and was asked to indicate the difficulty of each trial and their response confidence. For all conditions participants showed high response accuracy and high confidence in their responses, also reflected in low difficulty ratings. Detailed results of the doppelganger rating and the behavioral piloting are reported in the Supplementary Materials.

2.4. Study Design

There were three experimental conditions: identity, twin, and unrelated person implemented in the study. Each trial consisted of three successively presented images of people followed by two test questions (Fig. 1).

On the critical trials (identity & twin), two of the three faces were taken from the optimal similarity/dissimilarity pairs. Besides having similar facial features, they also wore white or grey T-shirts with either the same or different necklines. Necklines were used in counterbalanced fashion as a condition cue for being the same person or twins. The participants in our study had to identify individuals based on facial appearance and the neckline of their T-shirt. In half of the 18 critical trials, the pairs with similar facial features had the same neckline (nine trials), the other half had different necklines (nine trials). Participants were randomly assigned either to the instructions that the same neckline means same person and different necklines means twins or to being instructed that the same neckline means twins and different necklines means the same person. We used the combination of facial similarity and neckline as cues to identity for three reasons: (1) facial appearance and clothing are easily implemented in a person recognition paradigm; (2) it enables good control over visual stimuli across conditions, and (3) allows control over the reasoning processes for identification.

In the unrelated person condition (18 trials), none of the three faces were noticeably similar. This condition was to prevent participants to exclusively attend to the identity cues (shape of neckline) and not to the similarity of faces. Also, nine trials of rest (25%) were added. All persons within a trial were of the same gender. Trials of all three conditions were matched for response to the test questions, person's gender, T-shirt color, and shape of the neckline.

We presented three faces on each trial to increase stimulus variability and difficulty of the first test question, which asked how many people owned a white T-shirt. This question served as an orthogonal condition for an attention check and required participants to integrate identity processing into a counting task. For example, if two similar faces with white T-shirts are judged as identical, the count of persons with white T-shirts only adds 1. However, if similar faces with white T-shirts are judged as twins, the count adds 2. As some trials present similar faces without wearing white T-shirts we presented a second question at the end of each trial asking whether there were any similar faces, and if so, whether they belonged to the same or to different persons. Answering both questions correctly requires participants to closely attend to the presented faces and process to which individuals they belong. The images and the questions were presented for 4.0 s each with an interstimulus interval of 0.3 s resulting in a trial length of 21.5 s.

Responses were given on an MRI-compatible response pad using three buttons for responding with “0”, “1”, and “2” to the first question, and with “same person”, “twin”, and “other” to the second question. Stimulus delivery and response registration were controlled by Presentation (Neurobehavioural Systems Inc., Albany, CA, USA).

2.5. fMRI data acquisition and analysis

The experiment was conducted on a 3 T MRI scanner (Siemens Magnetom Trio, Siemens Medical Solutions, Erlangen, Germany) equipped with a 32 channel head coil. Functional images were acquired within one session (437 vol) with a T2*-weighted echo-planar imaging sequence (EPI) (3 × 3 × 3 mm^3, repetition time = 2250 ms, echo time = 30 ms, flip angle = 70°, matrix 64 × 64 mm, field of view = 192 mm). Six dummy scans were acquired at the start of the functional run to minimize transient signals. A high-resolution structural image with a T1-weighted MPRAGE sequence (1 × 1 × 1 mm^3, repetition time = 2300 ms, echo time = 2.94 ms, flip angle = 9°, matrix 256 × 256 mm, field of view = 256 mm) and a pair of field maps (phase and magnitude images) were acquired additionally. Preprocessing and analysis were performed using SPM12 (Wellcome Trust Centre for Neuroimaging, London, UK, http://www.fil.ion.ucl.ac.uk/spm) within a MATLAB 8.1 environment (Mathworks Inc., Sherborn, MA, USA). Data were spatially realigned, and slice-time corrected using sinc-interpolation. We coregistered the EPI images to the corresponding anatomical high-resolution image. Data were normalized into the MNI standard space (Montreal Neurological Institute) and spatially smoothed using a 6 mm FWHM Gaussian kernel.

Statistical analysis was implemented as a two-stage random effects model. For the first level model, experimental conditions included identity, twin, and unrelated person. For each subject, we modelled the correct response trials to reduce scan variability and to ensure that participants were accurately representing the faces. Onsets were modeled in a block design starting from the presentation of the first image to the third image. All regressors were convolved by a canonical hemodynamic response function. Six additional motion-regressors were modeled as covariates of no interest. Functional data were high pass filtered (cut-off 128 s) and corrected for temporal auto-correlation by an AR (1) model (Friston et al., 2002). Calculations of linear contrasts between parameter estimates are based on the signal change of the different conditions over rest. For the second level model, the main contrasts between identity and twin and between twin and identity were tested with two independent t-tests. The results were thresholded at $p < .001$ for voxel-level (uncorrected) together with a family-wise error (FWE) correction ($p < .05$) at the cluster-level.

3. Results

3.1. Behavioral data

For the critical conditions, identity and twin, the average percentage of answering both questions correctly at the end of each trial was significantly above chance (33.33%) for the first question (identity: M = 89.30, SD = 15.26, t (26) = 18.70, $p < .001$; twin: M = 92.59, SD = 9.56, t (26) = 31.60, $p < .001$) and the second question (identity: M = 70.78, SD = 24.41, t (26) = 7.82, $p < .001$; twin: M = 53.91, SD = 25.25, t (26) = 4.15, $p < .001$). There was no significant difference between the identity (M = 89.30, SD = 15.26) and twin (M = 92.59, SD = 9.56) for the first question (t (26) = -1.034, p = .311), but subjects performed significantly better for identity (M = 70.78, SD = 24.41) than for twins (M = 53.91, SD = 25.25) on the second question (t (26) = 3.49, p = .002). All tests were performed with Bonferroni adjusted alpha levels.

3.2. Neuroimaging data

To identify the brain areas engaged during identification of an individual, we looked for regions that showed stronger BOLD activation for the identity than for the twin condition (Identity > Twin; Table 1). This contrast was significant in medial prefrontal cortex, the left inferior frontal gyrus, thalamus, as well as bilateral inferior parietal lobe/

Table 1
Whole brain activation. The results are reported at a voxel-level threshold of $p < .001$ uncorrected together with a FWE-corrected cluster threshold of $p < .05$.

Label	MNI coordinates			T	Cluster
	x	y	z		
Identity > Twin					
Medial Prefrontal Cortex	3	62	13	5.09	408
Paracingulate Gyrus	15	38	19	4.80	
Cingulate Gyrus	3	29	13	4.44	
Right Superior Frontal Gyrus	18	26	46	4.28	73
Middle Frontal Gyrus	36	32	37	3.64	
Left Medial Prefrontal Cortex	−24	53	22	4.66	56
Paracingulate Cortex	−15	44	16	3.66	
Left Middle Frontal Gyrus	−39	8	49	5.18	253
Superior Frontal Gyrus	−24	−7	55	4.81	
Inferior Frontal Gyrus/Pars triangularis	−45	38	16	3.97	
Left Inferior Frontal Gyrus/Pars orbitalis	−45	26	−8	5.62	129
Inferior Frontal Gyrus/Pars triangularis	−54	23	22	4.87	
Right Thalamus	15	−13	16	4.33	55
Right IPL/Supramarginal Gyrus	45	−43	37	5.86	362
IPL/Angular Gyrus	39	−55	37	5.28	
Lateral Occipital Cortex	30	−73	43	5.34	
Left Lateral Occipital Cortex	−30	−73	40	4.88	210
IPL/Angular Gyrus	−36	−58	40	4.12	
IPL/Supramarginal Gyrus	−48	−40	52	3.91	
Precuneus	−12	−73	43	3.69	
Twin > Identity					
no suprathreshold clusters					

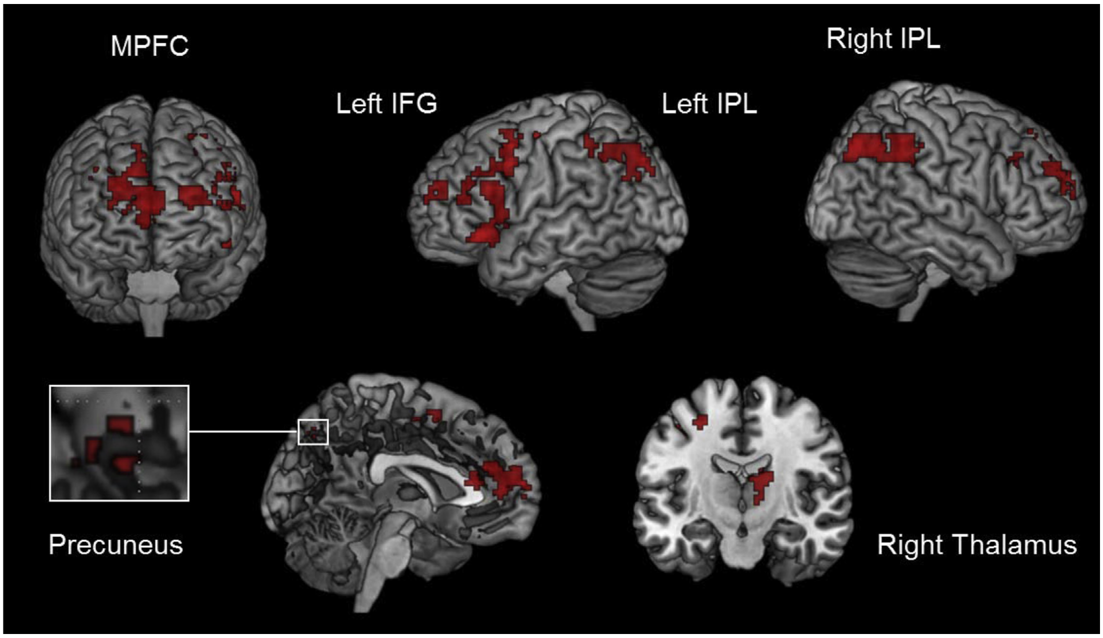

Fig. 2. Imaging Results. Whole brain activation of *Identity* > *Twin*. Difference in activation was found in the medial prefrontal cortex (MPFC), left inferior frontal gyrus (IFG), bilateral inferior parietal lobes (IPL), lateral occipital cortices, Precuneus and Thalamus.

temporoparietal junction, left precuneus, and the lateral occipital cortices (see Fig. 2). No brain regions showed a greater response for the reverse contrast (Twin > Identity; Table 1).

4. Discussion

In our present study participants had to judge pictures of highly similar faces as showing either the same person (identity condition) or two different persons (twin condition). To investigate the process of identifying someone as being the same person previously encountered we contrasted the identity condition with the twin condition. The results support our analysis that this process relies on an increased engagement of frontal and parietal brain areas including the left inferior parietal cortex/temporoparietal junction and the precuneus. For re-identifying an individual two separate representations (mental files) of the same individual have to be linked. This link is an informational mechanism that enables treating both files as representing the same individual, i.e., that the information stored in one file is also available from the other file. In the following section, we will discuss the limitations of our study, how mental files may extend our current view on recognition of identity and how the linking process relates to other fields of research (e.g., delusional misidentification syndromes, and theory of mind).

The participants in our study had to identify individuals based on facial appearance and a second non-facial cue, i.e., the type neckline of their T-shirt. It could be contended that this method might not reflect a natural process deciding whether it is the same individual previously encountered or two different individuals that share the same appearance. But we argue that human beings routinely employ various cues for identification. For example, studies have shown that our representations are influenced by spatiotemporal continuity. Individuals must trace continuous paths through space and time, and constraints like these determine whether one should infer the existence of a single or of two individuals from the current information available even when these individuals display no discriminating features (Yi et al., 2008). The use of spatiotemporal continuity has already been shown in four-month-old infants as well as in non-human primates (Flombaum et al., 2004; Spelke et al., 1995).

Other non-facial cues to identity involve the human voice, body features, gestures, movements, the gait of a person and even the clothing (Duchaine and Weidenfeld, 2003; O'Toole et al., 2002; Rice, Phillips, Natu, An, & O'Toole, 2013; Schweinberger et al., 2011; Stevenage et al., 1999). These cues may serve as an input for a causal reasoning process aiming for person identification, and they become more critical when facial identity recognition is constrained (Fields, 2016). Patients with prosopagnosia who are not able to immediately recognise faces rely on these cues as a compensatory strategy (Behrmann and Avidan, 2005). Hence, these cues do play an important role in identity recognition, and human beings use these cues very naturally. The results of the current study extend our understanding of person identification. The identity of an individual can be recognised via two different cognitive routes. The first and central route is used when the percept of an individual causes the corresponding mental file to be immediately retrieved from memory. This file has stored information (memory) and new information from current perception can be added, so there is only a single file involved and no linking of files takes place. The identity is established through the subject's non-conceptual capacity to recognise the individual and track it over time (Recanati, 2012). This recognition process is primarily based on being familiar with the individual to be recognised. Research on recognising familiar faces developed sophisticated models to explain this process and its neurofunctional implementation (Haxby et al., 2000; Gobbini and Haxby, 2007).

The second route is used when immediate recognition has failed. A new mental file is created for the newly encountered individual. Upon recognising that this individual is already known and a file for it exists in memory, the new file has to be linked to its existing co-referential file in memory. The process of linking two files establishes the identity of the files' referent and it enables an informational exchange between the files (Recanati, 2012). This process is primarily metacognitive, as it does not provide new information about the referent but changes how one thinks about the referent. It is based on computational resources that are localizable in the brain. As our study shows it involves a network comprising the medial prefrontal cortex, thalamus, left inferior frontal gyrus, bilateral inferior parietal cortex/temporoparietal junction, precuneus and lateral occipital cortices. The process of linking files is not specific to person identification, i.e., our findings should be generalizable also to other domains. We anticipate the same process for identifying animals, inanimate objects, places or events in future studies.

Our results are in line with findings from patient studies with delusional misidentification syndromes. These syndromes characterize specific impairments in the processing of identity (for a review see, Darby and Prasad, 2016). The most prominent of these syndromes is the Capgras delusion. Patients with Capgras delusion attribute a new identity to a familiar person. They fail to identify individuals as being the same even when they are utterly familiar to them (e.g., their wife). They fail to do so even though they are unimpaired in recognising the high similarity between the currently encountered and the known individual (Hirstein and Ramachandran, 1997). Seeing the high similarity, yet unable to recognise their identity, patients conclude that, e.g., their wife, must be an impostor (Ellis and Lewis, 2001).

Wilkinson (2016) describes these delusions as mismanagement of mental files and identifies two processing errors: Patients with Capgras delusion fail to retrieve the file for the familiar individual in immediate recognition, and then fail to link the mental file for the person in front of them to the file for the familiar person. This view is in line with Darby and Caplan (2016) argument that the symptoms of delusional misidentification may result from a dysfunction of linking the perceptual representation of an individual with the existing representation of this individual in autobiographical memory. This dysfunction also explains why delusional misidentifications also have been described as a disorder of the sense of uniqueness or identity (Margariti and Kontaxakis, 2006). The Capgras patient may lack the ability to link co-referential files resulting in the breakdown of the identification process and denial of identity.

Delusional misidentification syndromes, like the Capgras delusion and other forms of misidentification, are linked to neurological injuries predominantly located in the right frontal hemisphere. The lesions are functionally connected to several areas identified in our study: the frontal cortex, the precuneus, and the left and right temporoparietal junction (Darby et al., 2017). Moreover, delusional symptoms may not just be caused by the lesion itself but also by brain regions that are functionally connected to it (Crossley et al., 2014; McKay and Furl, 2017). This view is corroborated by a recent fMRI study of a patient with Capgras delusion (Thiel et al., 2014). The patient with a right prefrontal lesion lacked neural activity in response to her partner's face in the left posterior cingulate cortex/precuneus and the left temporoparietal junction (superior temporal sulcus).

Delusional misidentification syndromes can be distinguished as hypo- and hyper-identification of persons, places, events, or objects (Christodoulou et al., 2009). In case of the Capgras delusion (a form of hypo-identification), the perceptual file of an individual cannot be linked to the memory file of that individual, and thus the individual is seen as someone who looks very similar but is a different person claiming to be the familiar person. He/she, therefore, must be an impostor. The deficient file process might also explain reduplicative phenomena in the context of Capgras delusion where patients report that the individuals' impostor has again been replaced by another imposter and so forth (Capgras & Reboul-Lachaux, 1994; Wilkinson, 2016). Upon a new encounter the patient erroneously creates a new mental file for a given individual without being able to link the new perceptual file with the memory file. These further reduplications result in the subjects' belief that there are multiple imposters of a given individual. The Fregoli delusion (a form of hyper-identification) can be characterized by an erroneous linkage of the perceptual file with an unrelated memory file (Wilkinson, 2016). This leads to the belief that the unknown perceived individual is identical with the known person despite differences in visual appearance, which is then interpreted as the known person being in disguise.

Hypo- and hyper-identifications might consequently be caused by a hypo- or hyperactive linking mechanism for co-referential files. A comprehensive review (Darby and Prasad, 2016) showed a noticeable number of coexistence (10%) of hypo- and hyper-identifications in the same patient. This suggests a common mechanism of all delusional misidentifications syndromes. This commonality has also been demonstrated on the neuronal level by showing a similar pattern of lesion-related resting-state connectivity for both cases in delusional misidentification syndromes. Darby et al. (2017) showed that lesions in the frontal cortex were functionally connected to the right ventral frontal cortex, the precuneus, and the left and right temporoparietal junction – cortical areas that were also found in our study.

Mental files theory also provides a theoretical explanation of why questions of identity co-occur with theory of mind in development (Perner et al., 2011) and neurological syndromes noted by Hirstein (2010) describing 'misidentification syndromes as mindreading disorders'. He argued that delusional misidentifications are due to failures of the mentalizing system, a set of brain processes we use to understand and predict other people's behaviour. This relationship between identity recognition and theory of mind has also been observed by Gobbini and Haxby (2007). The recognition of individuals may include the retrieval of 'person knowledge', i.e., the representation of personal traits, intentions, mental states, and biographical knowledge, knowledge based on a theory of mind. In support of this view, Greven et al. (2016) found a task-based functional coupling between areas selective for face processing and hubs of the mentalizing network.

Mental files theory provides a more direct explanation of this connection between identification and theory of mind. In both cases, co-referential files need to be linked. In the case of theory of mind, we form co-referential 'vicarious files' to capture people's beliefs and perspectives about objects (Perner and Brandl, 2005; Recanati, 2012). Without linking one's vicarious files to one's own regular files, one could not understand that the other person's mental states are about the same world as one's own. In the case of identification, we deploy co-referential files for representing the same individual as being currently encountered and as having been encountered previously. Linking both files ensures they are being treated as representing the same individual. This process seems to be deficient in delusional misidentifications.

5. Conclusion

We have isolated the process of identifying a perceived individual as that individual remembered from a previous encounter. We found activation differences in the medial prefrontal cortex, left inferior frontal cortex, left and right inferior parietal lobe, precuneus, lateral occipital cortices, and the thalamus. Couching our findings in the theoretical framework of mental files helped us identify important connections among several different fields of psychological enquiry, which involve identification or misidentification of individuals. Imaging evidence from various fields together with our results suggest that in particular the left inferior parietal lobe and the precuneus are consistently associated with identity processing, i.e., linking of co-referential files. Finally, mental files theory allows explaining why misidentification syndromes have been linked to theory of mind deficits because theory of mind also requires identification of objects as seen from one's own vantage point with the same object as seen from another person's perspective. In sum, the process of identification is a pervasive skill that has largely gone unnoticed in psychology and cognitive neuroscience.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.neuropsychologia.2019.03.019.

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