Accessing stored knowledge of familiar people from faces, names and voices: A review

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1. ABSTRACT

Recent findings from neuropsychology and experimental psychology appear incompatible with the claim that feelings of familiarity about known people require activation of amodal person identity nodes. Evidence suggests that there are modality-specific effects after the point at which faces, names and voices have been found familiar. It therefore appears that activation of distinct modality-specific face, name and voice processing systems can signal that a known person is familiar. There is no convincing evidence, however, of modular effects on the way that information about familiar people is represented in semantic memory. Instead, semantic information about people appears to be stored separately from other forms of knowledge such as knowledge of objects. Anatomical evidence suggests that amodal person-specific semantic knowledge is stored in the right anterior temporal lobe where it has close connections with modality specific recognition systems. Failures to retrieve names in proper name anomia may be caused by impairments to the links between semantic knowledge in the right anterior temporal lobe and lexical representations in the left temporal pole.

2. BURTON *ET AL.*'S (1990) IAC MODEL OF PERSON RECOGNITION

2.1. Summary

Just over 20 years ago, Burton, Bruce and Johnston put forward a highly influential interactive activation and competition (IAC) connectionist model that simulated the way in which stored knowledge about familiar people is retrieved from the cognitive system (1). In this model, the system involved in identifying faces, names and voices contains modality-specific *recognition units* that respond in the presence of known faces (FRUs), names (NRUs) and voices (VRUs). According to Burton *et al.*'s account, the knowledge that a face or name or voice is that of a familiar person is not available to the rest of the cognitive system until these modality specific systems have converged into an amodal *person* recognition system. So, for example, activation to threshold of an abstract *person identity node* (PIN) node rather than a modality specific FRU is required before a known face starts to feel familiar. This account differs from the earlier view, advocated by Bruce and Young (2), in which activation of an FRU is in itself sufficient to allow a perceiver to distinguish overtly a familiar from an unfamiliar face.

Excitation of a PIN in Burton *et al.*'s IAC model also leads to activation of a separate amodal semantic information pool that allows the retrieval of *semantic information units* (SIUs) about a person such as their occupation or where they are typically encountered. Consistent with Bruce and Young (2), Burton *et al.*'s model therefore assumes that stored knowledge about a person is retrieved from the same semantic information pool regardless of whether their face is seen, their voice is heard or their name is read.

2.2. Neuropsychological evidence consistent with the IAC model

Burton *et al.*'s (1) claim that the ability to distinguish familiar from unfamiliar people involves activation at the level of an amodal PIN was able to provide a satisfactory explanation of the findings from a number of important investigations of person recognition impairments that were published during the late 1980s and 1990s. These findings are summarized below.

Difficulties experienced by patients who no longer found known people to be familiar and were unable to recall semantic information about them from either their face, name or voice (e.g. 3-5) could be economically explained in terms of a single problem at the level of the PINs that impairs performance in all three modalities.

The performance of a patient who could consistently match familiar faces to their names despite being unable to access semantic information about the people concerned could be explained in terms of preserved activation of the PINs (6). Joint activation of a PIN would allow the matching of a face to a name despite weakened connections between the PIN and the SIU that prevented recall of semantic information.

As Young and Burton (7) pointed out, the IAC model also provided a persuasive explanation of the covert recognition of faces in acquired prosopagnosia. For example, the performance of prosopagnosics who showed strong associative priming of familiar names from faces that they could no longer recognize *overtly* (8-9) was successfully simulated by reducing the strength of the connections between FRUs and PINS in the IAC model (10). These associative connections could be reduced so that they were too weak to allow once-familiar faces to activate PINs to threshold, but remained strong enough to allow these faces to prime familiar names via residual activation of shared semantic features.

Nevertheless, alternatives to the account put forward by Burton and his colleagues have started to emerge in recent years. Consistent with the views of Bruce and Young (2), neuropsychological data is now available to suggest that decisions that a person is familiar are associated with activation of modality specific recognition systems (11). It has even been suggested (12-13) that the semantic system that contains knowledge about familiar people may differ according to whether the semantic information is associated with names (verbal semantics) or faces (visual semantics). These two areas of research are discussed below.

3 PROBLEMS FOR THE IAC MODEL

3.1. Distinguishing familiar and unfamiliar voices

A problem for Burton *et al.*'s (1) model is the finding that voice identification by unimpaired participants is associated with large numbers of familiar-only experiences in which a voice feels familiar but semantic information about the person cannot be recalled (14). It appears to be much more difficult to recall semantic (15-16) or episodic information (17-18) from voices that are found familiar than from faces that are found familiar. Such findings are observed with voices of famous people and with voices that are known in everyday life so long as care is taken that a voice cannot be identified from the semantic content of what is being said. Moreover, information about a familiar person is more difficult to recall from voices than faces even when the rated familiarity of the voices and faces is the same, and even when hit rate and sensitivity are matched in the face and voice conditions by blurring the faces (for further discussion, see 19-20). The occurrence of modality specific differences after faces and voices have been found familiar is incompatible with the claim that decisions that a person is familiar are made beyond the point at which the face and voice have merged into a single amodal person recognition system.

3.2. Failure to recall semantic information in one modality

It is equally difficult for Burton *et al.*'s (1) account to explain some neuropsychological cases who produce unusually large numbers of familiar-only responses in just one modality (11, 21-23). The individuals described by Semenza *et al.*(21) and Van der Linden *et al.* (22) found known faces and names familiar but could recall semantic information about people in response to their names but not in response to their faces. For example, Semenza *et al.*'s patient was able to distinguish a famous from an unfamiliar face on 70/70 trials on a forced choice test, but could not recall accurate semantic information about any of these 70 faces. When shown their name, however, his ability to recall semantic information was unimpaired. Verstichel *et al.* (23) reported a case with the opposite impairment who found virtually all famous names and faces familiar, but was impaired at recalling semantic information about these people from their names but not from their faces.

Clearly, such cases are relatively easy to explain if decisions that a person is familiar are taken by modality-specific mechanisms. However, Van der Linden *et al.* (22) showed that the IAC model (1) could also provide a plausible explanation of their case. They suggested that activation of the PIN from name recognition units (NRUs) was normal. When viewing a familiar face, however, there might have been enough activation of the PIN for it to reach the threshold for familiarity, but insufficient activation to allow information about the person to be retrieved from the semantic information pool. Such an outcome can be readily simulated by the IAC model (24-

25). Nevertheless, it is difficult to believe that this account could be satisfactorily applied to Semenza *et al.*'s (21) case because this individual's performance when distinguishing familiar and unfamiliar faces was faultless.

Gainotti *et al.* (11) provided further evidence that was difficult for such an account to explain. They described a woman (StG) with left anterior temporal lobe damage whose ability to distinguish between famous and unfamiliar names was just below the median level of controls. Her ability to recall semantic information from these names was severely impaired. Moreover, Gainotti *et al.* reported a second patient (VL) with right anterior temporal lobe damage whose ability to recall semantic information from familiar names was unimpaired even though his ability to distinguish famous from unfamiliar names was equivalent to that of StG. Because the recognition rate for familiar names was similar in these two cases, it does not appear reasonable to argue that StG's selective inability to recall semantic information about names occurred because the activation level of the PIN was lower for StG than for VL. As Gainotti *et al.* pointed out, this dissociation is much more easily explained if it is assumed that StG has suffered an impairment to the connections between the NRUs and the semantic information pool.

For both neuropsychological cases and normal participants, therefore, there is evidence of modality-specific differences beyond the point at which people have been deemed familiar that are inconsistent with Burton *et al.*'s (1, 25) claim that decisions that a person is familiar are made by amodal PINs. Instead, Gainotti *et al.* (11) argued that the decision that a name or face is that of a known person is made as a result of activation of, respectively, the name processing system in the left hemisphere and the face processing system in the right hemisphere (see also 26). The anatomical locus of these modality-specific recognition systems for names and faces will be further discussed towards the end of this article.

4 ALTERNATIVES TO AMODAL PINS

4.1. Modality specific systems for decisions that a person is familiar

Nevertheless, abandoning Burton *et al.*'s (1) account of the PIN as the point at which a person is identified as being familiar does have some potential disadvantages. As we have seen, difficulties experienced by patients who no longer found many known-people to be familiar and were unable to recall semantic information about them from either their face, name, or voice (3-5) could be economically explained by Burton *et al.*'s model in terms of a single impairment at the level of the PINs. The alternative is that these individuals have separate impairments to the voice, face and name recognition systems. Although this account is less parsimonious, it would be plausible if recognition units for names, faces and voices are stored in adjacent areas of the brain. Such a possibility will be discussed in detail later in the article.

Preserved activation of the PINs but weakened connections between the PINs and the SIUs in Burton *et al.*'s IAC model can also neatly explain the ability to match

a person's face and name even when semantic information was not recalled (6). A possible alternative is that the semantic representations of these people were activated sufficiently strongly to allow their faces and names to be matched but were not activated strongly enough to allow overt retrieval of that material.

If Burton *et al.*'s (1) claim that decisions that a person is familiar are made at an amodal PIN is rejected, then it is no longer possible to explain covert recognition in prosopagnosia in terms of normal activation of FRUs but weakened connections between the FRUs and PINs. If so, prosopagnosics would show overt as well as covert recognition of known faces. One possible alternative is that the impairment in prosopagnosia reflects activation of the FRUs that is too weak for overt recognition but is sufficient for covert recognition to occur. It has been shown that an architecture of this kind can provide a plausible simulation of covert recognition in prosopagnosia (27). Such an account also provides a parsimonious interpretation of the finding that some 'associative' prosopagnosics show covert recognition while other 'apperceptive' prosopagnosics do not (28). This distinction between apperceptive and associative prosopagnosia can then be re-conceptualised as a continuum along which the activation of face recognition units in prosopagnosia varies as a function of the severity of the visual processing impairment (29-30).

4.2. Two recognition routes?

One way in which the IAC model might be modified to accommodate modality effects would be to incorporate an additional recognition route with relatively weak connections to the semantic information pool (31). According to such an account, there might be a secondary mechanism for determining that a person is familiar that is related to the system that provides elevated skin conductance responses when known faces, names or voices are encountered. If decisions that voices ares familiar are made relatively often by this secondary route, then it would be possible to explain why voices that are found familiar often fail to elicit any semantic information (e.g. 16). In the case reported by Semenza *et al.* (21), it might be argued that access to semantic information from a name is possible because his ability to distinguish familiar from unfamiliar names reflected activation of the PIN. Access to semantic information might be weaker from faces than from names, however, if the secondary system is responsible for his preserved ability to distinguish familiar from unfamiliar faces. In the case of StG (11), it could be argued that the opposite is true. This approach makes it possible to maintain Burton *et al.*'s (1) claim that decisions that a face or name is familiar require activation of an amodal PIN, but at the expense of an obvious reduction in parsimony and predictive power.

In conclusion, it is possible that some theorists may feel that the additional recognition route suggested by Schweinberger and Burton (31) is a price worth paying in order to retain the explanatory power of the idea that distinguishing familiar from unknown people involves activation of an amodal PIN. Nevertheless, many others will feel that a more plausible and parsimonious

explanation of research on person recognition difficulties is possible if it is assumed instead that the familiarity of a face, name or voice is initially signalled by the modality specific recognition systems themselves (2).

5. MODALITY-SPECIFIC OR AMODAL SEMANTIC SYSTEMS FOR PEOPLE?

In this section, three different accounts of the way in which knowledge about familiar people is represented in the brain are discussed. The first two accounts differ in important ways, but are both consistent with the view that semantic knowledge about familiar people is represented amodally (1-2). The third account, however, provides a potentially important challenge to this viewpoint.

5.1. Semantic hub model

The semantic hub model represents an attempt to explain semantic memory deficits experienced by patients with semantic dementia who have suffered atrophy to the anterior temporal lobes (32). It is claimed that the anterior temporal lobes provide an amodal hub that integrates information with similar semantic content even when it is acquired via different modalities. In terms of representations of familiar people, the semantic hub will therefore integrate information about a person that is acquired when reading or hearing their name, when listening to their voice or when seeing their face. The location of the anterior temporal lobes means that semantic information is stored in an area that is conveniently close to the episodic memory stores in the medial temporal lobes and the emotion system in the amygdala and limbic system (32). However, supporters of this model made no claim that semantic knowledge about people in the hub is stored separately from knowledge of other semantic categories (32).

5.2. Categorical representation of semantic information about people

Following Caramazza & Shelton (33), who argued that knowledge is fractionated into distinct semantic memory systems (e.g. for animals, plants and artifacts), several authors subsequently suggested that knowledge about conspecifics is also stored in its own distinct area of semantic memory (34-37).

One important observation was that patients such as KS (3), BD (4, 38) and JP (37) were unable to recall semantic information about many once-familiar people despite being either unimpaired (JP, KS) or much less impaired (BD) at retrieving the properties of common objects. Since then, convincing evidence of a double dissociation between retrieval of general semantic knowledge and knowledge of people has emerged. Several individuals with preserved knowledge of familiar people who have severe problems in retrieving information about objects from semantic memory have been reported (35, 37, 39- 41). These patients could recall semantic information about people despite performing badly on the Pyramids and Palm Trees (42) test of general semantic knowledge. For example, Haslam and Sabah (39) described two patients with dementia whose knowledge of familiar people remained unimpaired even though their performance on tests of general semantic knowledge declined steadily over time.

This categorical account differs from the semantic hub model in assuming that knowledge about conspecifics is stored separately from other types of semantic information. Nevertheless, the categorical account is consistent with the semantic hub model in assuming that semantic knowledge about people is stored amodally in the anterior temporal lobes. For example, BD, KS and JP were severely impaired at recalling semantic information about people regardless of whether their name, face or voice was presented for identification. JP also performed relatively well on the Pyramids and Palm Trees test regardless of whether it was presented in verbal or visual form. Equally important, patients with preserved knowledge of people despite impaired general semantics (39, 41) performed well on a test of person knowledge that required retrieval of semantic information from familiar names in addition to performing well at identifying famous faces. They performed poorly on tests that required naming objects and poorly on tests that required retrieval of semantic information about the names of objects. There is no evidence, therefore, that any of these patients had a modality specific impairment (see below) rather than a categorical impairment.

BD (4) and KS (3) also provided early anatomical evidence for the view that semantic information about people is stored in the *right* anterior temporal lobe (43). KS had undergone an anterior temporal lobectomy in the right hemisphere to treat her epilepsy, and BD had particularly severe damage in the right temporal lobe following herpes encephalitis. Patients with semantic dementia such as Emma (34), VH (44) and JP (37) experienced multimodal difficulties in recalling information about familiar people as a result of progressive degenerative diseases in which atrophy was much more pronounced in the right than the left ATL.

Consistent with this viewpoint, PET and FMRI studies consistently demonstrate that the right anterior middle temporal gyrus is activated when either faces or names of familiar people are being processed (e.g. 45-46) and when familiar voices are being processed (47). The anterior temporal lobes also have strong connections with the Fusiform Face Area (FFA) (e.g. 48) in the lateral part of the middle fusiform gyrus, an area that is strongly associated with impaired face recognition in acquired (e.g. 49) and congenital prosopagnosia (e.g. 50). The claim that semantic knowledge about people is associated with right rather than left hemisphere storage is also consistent with the finding that patients with prosopagnosia can suffer from unilateral right-sided occipito-temporal lesions as well as from bilateral lesions, but not, it appears, from a unilateral left hemisphere lesion (e.g. 29).

There is also evidence that the right hemisphere anterior temporal lobes play a lesser role in the retrieval of information about familiar objects. Many years ago, Wilkins and Moscovitch (51) showed that a left anterior

temporal lobectomy impaired the ability to make semantic decisions about pictures and names of familiar objects whereas performance by patients with right anterior temporal lobectomies showed no signs of impairment on this task. Unlike individuals such as BD, KS and JP, patients who have severe problems in recalling semantic information about objects despite preserved knowledge of familiar people typically have lesions or atrophy that is more pronounced in the left rather than right hemisphere (e.g. 37, 39).

According to advocates of the hub model (32, 52), these dissociations do not indicate that semantic knowledge about people is represented unilaterally in the right hemisphere. Such knowledge is represented bilaterally, they claim. However, the fact that the face (and voice) processing system is represented predominantly in the right hemisphere means that the face processing system will develop particularly strong connections with the right ATL. It is damage to these connections that produces disproportionately poor recognition of faces by patients such as JP (37) who have selective right hemisphere atrophy. However, it is not clear that the semantic hub model can provide an equally plausible account of JP's impaired identification of people's names.

5.3. Modality specific semantic knowledge of familiar people

Several authors have suggested that the form in which semantic knowledge is represented differs in the left and right anterior temporal lobes (12-13, 26, 53). Their claim is that verbal semantic knowledge is stored in the left hemisphere and visual semantic information is stored in the right hemisphere. This means that semantic information about names of people is stored in the left hemisphere and semantic information about their faces is stored in the right hemisphere. The distinction between the storage of visual and verbal semantic information applies equally to semantic knowledge about objects. According to this view, therefore, the key distinction between what is stored in the left and right ATL is modality (verbal knowledge versus visual knowledge) rather than category (knowledge of objects versus knowledge of people).

Eslinger et al. (53) claimed to have provided evidence in favour of modality differences in semantic storage. They reported a case (DR) with better recall of semantic information about people from their names than from their faces following a right temporal lobe lesion. They reported another case who was better at recalling semantic information about people from their faces than names following a left temporal lobe lesion (EK). However, DR's performance was more impaired when distinguishing known and unknown faces than known and unknown names, and EK's performance was more impaired with names than faces. However, the differences in recall of semantic information from faces and names that these two patients show may therefore reflect modality differences in processing that occur prior to semantic access (54).

Snowden et al. (12) examined the performance of ten semantic dementia patients for whom neuroimaging

had revealed greater left than right-sided atrophy. These individuals performed significantly better on tests of famous face identification than on tests of famous name identification. Although severely impaired on both tasks relative to controls, their performance was significantly better on a forced-choice familiarity test for faces than names, and they retrieved more semantic information about these people from their faces than from their names. Patients with more right than left-sided atrophy showed the opposite pattern, although the sample size was small (n = 3) and the differences did not reach statistical significance.

Snowden et al. (13) reported a follow-up study that used the same patients plus one additional participant with greater right than left-sided atrophy. Snowden et al. argued that if semantic information is represented amodally in the right ATL then there should be a correlation between the ranking of an individual's performance on the name and face identification tasks. However, the results revealed no such relationship. Instead there was a strong relationship between a patient's performance on name identification tests and the Pyramids and Palm trees test for words.

Unfortunately, neither of Snowden et al.'s (12-13) studies provide unequivocal evidence for modality-specific semantic representations of familiar people. So long as it is acknowledged that decisions that names are familiar are taken by modality-specific name recognition units, and familiarity decisions about faces are taken by modality-specific face recognition units, the results can be easily explained in terms of an amodal semantic system for people. The simplest explanation of Snowden et al.'s (12) data is that the semantic dementia patients with right-sided atrophy could retrieve more semantic information about people from faces than names simply because they found more faces than names familiar. The correlation between performance on name identification and the Pyramids and Palm Trees tests for words (13) is readily explicable in terms of the left ATL playing an important role in both name recognition and the representation of semantic knowledge for objects. Patients with more extensive left hemisphere atrophy will be likely to show greater impairment on both tasks.

In conclusion, therefore, there is a lot of evidence for a distinction between the semantic information that is stored in the left and right ATL. This evidence strongly suggests that the basis for this distinction is categorical (objects versus people) rather than being based on modality (verbal versus visual).

6. ANOMIA

Individuals with proper name anomia can often remember a person's occupation or where they are typically encountered but have severe problems in producing their name (55) despite being unimpaired at retrieving names of objects. According to proponents of the IAC model (56), names are stored in the same semantic pool as other information about people but are more difficult to recall because they are unique. In a simulation using the IAC model, a fact that applied to several known people (e.g. an occupation) was retrieved more easily than unique

information such as an individual's name (56). If this account is true, patients with anomia should have as much difficulty in recalling highly distinctive semantic information about people as their name. In many cases of proper name anomia such as BG (57), however, semantic knowledge of people appeared to be fully intact. BG could recall unique facts (e.g. a catchphrase associated with a particular British celebrity) about 15/20 famous faces (control mean = 13.2/20) despite being able name only 1/20 of them (control mean =12.0/20). Evidence of this kind suggests that lexical representations of names are stored in a separate pool from semantic information about people such as their occupation or nationality (2, 58).

It has recently been claimed that the area of the brain in which lexical representations of names are stored is the left temporal pole. For example, PET studies with normal participants have shown maximal activation of Brodmann area 38 in the left temporal pole during retrieval of people's names (59). There is also evidence that surgical removal of the uncinate fasciculus, a structure that has strong connections with the temporal pole, leads to problems in proper name retrieval (60). Although the left temporal temporal pole and uncinate fasciculus are clearly involved in lexical retrieval, it is not yet established that these areas are *selectively* involved in the retrieval of proper names. There is evidence from lesion studies in aphasia that the left temporal pole, including Brodmann area 38, also plays an important role in activating lexical representations during object naming (61). In Papagno *et al.*'s (60) study, removal of the uncinate fasciculus appeared to have a significant detrimental effect on object naming also. So it may be the case that lexical representations of both common and proper names are stored together in the left temporal pole (for further discussion see 62). But if so, what is the cause of proper name anomia?

The possibility that the names of people are simply more difficult to recall than the names of objects seems unlikely given that there is now evidence of a type of anomia in which retrieval of the names of people is selectively *spared* (40, 63). Instead Semenza (64) suggested that it is the connections between person knowledge in the right hemisphere and lexical representations in the left hemisphere that are impaired in proper name anomia. Consistent with this suggestion, transcranial stimulation of the right anterior temporal lobes in neurologically unimpaired participants significantly improved the accuracy of the naming of famous people (65). Stimulation of the left anterior temporal lobes had no corresponding effect.

7.   ANATOMICAL   CORRELATES   OF FAMILIARITY MECHANISMS

Evidence has so far been presented that patients with impaired knowledge of familiar people have suffered damage to areas of the right anterior temporal lobes where semantic information about known people appears to be stored. In proper name anomia, it was suggested, this information is preserved but may have become

disconnected from lexical representations of names in the left temporal pole. In the final section, some possible anatomical locations of recognition units for faces, names and voices will be discussed.

7.1. Face recognition units

If there is strong evidence that modality specific recognition units play a key role in determining that a person is familiar, an important question is whether the initial feeling of familiarity reflects activation in an area of the brain other than the right ATL. One view is that FRUs are located in the fusiform face area (43, 66). As Bruce and Young (66) acknowledged, however, the neuroimaging data provide only limited evidence that the FFA is itself sensitive to differences in the identity of familiar faces. Kriegeskorte, Formisano, Sorger, and Goebel's (67) imaging data suggests a somewhat different account. They found that the FFA responded strongly to images of faces relative to other visual stimuli such as buildings. However, it was the right ATL rather than the FFA that responded differentially to images of different faces.

Data from patients with face identification problems are consistent with these findings. There is clear evidence that the absence of overt face identification in acquired prosopagnosia is associated with damage to the FFA and to its connections with the anterior temporal lobes (e.g. 68). Importantly, however, Busigny, Robaye, Dricot, and Rossion (69) reported a semantic dementia patient who was impaired at distinguishing familiar and unfamiliar faces even though neuroimaging results indicated that his occipital and fusiform face areas appeared to be completely intact. This patient, crucially, had atrophy of the right ATL.

A strong possibility, therefore, is that the FFA is associated with structural analyses of faces, but the structural code that it generates must activate a face recognition unit in the right ATL in order to produce a feeling of familiarity. In acquired prosopagnosia, it seems possible that FFA damage will either impair structural processing of faces or weaken the connections between the FFA and the FRUs in the ATL. The outcome will be a failure to activate FRUs sufficiently strongly for feelings of familiarity to occur in the presence of known faces. In cases of semantic dementia, however, disruption of face recognition units seems to be the result of extensive damage to the right ATL itself. In the case of VH, (44), a patient with semantic dementia initially experienced a recognition disorder associated with faces that gradually developed into a cross-modal person recognition deficit. It seems likely that there was relatively localised atrophy in the early stages of the disease that initially disrupted only the FRUs. Subsequently the atrophy became more widespread impairing name and voice recognition units also.

7.2. Voice recognition units

Bethmann, Scheich and Brechmann's (70) fMRI study of voice processing in normal participants identified the right ATL as the key area directly involved in distinguishing familiar from unfamiliar voices. A recent examination of the anatomical correlates of voice

recognition disorders in a sample of Alzheimer's and semantic dementia patients using voxel-based morphometry (71) also strongly implicated the right ATL as well as the fusiform gyrus. Moreover, Hailstone, Crutch, Vestergard, Patterson and Warren (72) reported a phonagnosic case who had a severe impairment in distinguishing familiar from unfamiliar voices that was associated with right ATL damage. Her structural processing of voices seemed to be preserved because she was able to discriminate between different unfamiliar voices. Her ability to retrieve semantic information from faces or names was also relatively well preserved. It therefore seems reasonable to conclude that right ATL atrophy had disrupted her voice recognition units but was not yet extensive enough to impair her face or name recognition units. As Hailstone *et al.* (72) pointed out, this case of phonagnosia seems to provide an interesting parallel to cases of prosopaganosia that are observed in the early stages of semantic dementia before the impairment develops into a cross-modal person recognition deficit (e.g. 44).

Gainotti (73) argued that it is a lesion of the right superior temporal gyrus rather than the ATL that may be the cause of selective voice identification problems. As Belin *et al.* (47) pointed out, however, it seems appropriate to distinguish voice identification problems associated with earlier structural processing impairments from those that are associated with later components of the voice identification process. Bethmann *et al.*'s (70) imaging study indicated that the right superior temporal sulcus is more likely to be involved in the structural processing of voices than in identifying familiar voices. A lesion in this area could nevertheless prevent familiar voice identification by impairing structural processing of voices, just as damage to the structural processing of faces appears to be a cause of prosopagnosia.

7.3. Name recognition units

As we have seen already, many patients with right rather than left ATL lesions (e.g. 3-4) or atrophy (37) perform poorly on all person recognition tasks including decisions as to whether famous names are familiar or unknown. BD (4) was as impaired at distinguishing famous from unknown names as he was at distinguishing famous from unknown faces. So it is not the case that name recognition impairments that are associated with right hemisphere lesions are always relatively mild. These findings suggest that name recognition units may be located in the right rather than the left hemisphere (for the opposite view see 30, 74-75). It might seem strange to distinguish lexical representations for names in the left hemisphere from name recognition units in the right hemisphere. Nevertheless, several models of name recognition (e.g. 76-77) draw a distinction between lexical units (equivalent to structural codes for names), and name recognition units that indicate that a name is that of a known person.

Conversely, Gainotti *et al.* (30) argued that decisions that a famous name is familiar involve activation in the left rather than the right hemisphere. Gainotti's (26) review of the literature revealed very few reports of individuals with a selective deficit in distinguishing familiar from unknown names. However, as we have already seen, there are several cases with left temporal lesions who have selective problems in retrieving semantic

information about names they find familiar (e.g. 23, 30). The obvious explanation of these cases is that name recognition units in the left temporal lobes have become disconnected from semantic knowledge about people in the right ATL.

It is difficult to reconcile these two sets of findings unless the patients with apparent unilateral right hemisphere lesions also had some damage to task-relevant left hemisphere structures, or the patients with apparent unilateral left hemisphere lesions also had some damage to task-relevant right hemisphere structures. Consequently, the precise neural bases for deciding that a name is that of a familiar person remain unclear at the present time.

8. CONCLUSION

In conclusion, recent research on person recognition suggests that modality-specific recognition units for faces and voices are associated with the right ATL, and that recognition units for names are associated with either the left or right temporal lobes. These units appear to serve as gateways between amodal semantic knowledge about people that is also stored in the right ATL and areas responsible for the structural processing of faces (FFA), the structural processing of voices (superior temporal sulcus) and the structural processing of names (left temporal lobe). The role of these modality-specific recognition units is therefore consistent with the idea of convergence regions (78). Contrary to the IAC models (1, 58) it appears that these modality specific units are connected directly with amodal semantic knowledge about a person and are themselves responsible for deciding that a known person is familiar.

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