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RECOGNIZING AND IDENTIFYING PEOPLE: A neuropsychological review

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Abstract

Recognizing people is a classic example of a cognitive function that involves multiple processing stages and parallel routes of information. Neuropsychological data have provided important evidence for models of this process, particularly from case reports; however, the quality and extent of the data varies widely between studies. In this review we first discuss the requirements and logical basis of the types of neuropsychological evidence to support conclusions about the modules in this process. We then survey the adequacy of the current body of reports to address two key issues. First is the question of which cognitive operation generates a sense of familiarity: the current debate revolves around whether familiarity arises in modality-specific recognition units or later amodal processes. Key evidence on this point comes from the search for dissociations between familiarity for faces, voices and names. The second question is whether lesions can differentially affect the abilities to link diverse sources of person information (e.g. face, voice, name, biographic data). Dissociations of these linkages may favour a distributed-only model of the organization of semantic knowledge, whereas a ‘person-hub’ model would predict uniform impairments of all linkages. While we conclude that there is reasonable evidence for dissociations in name, voice and face familiarity in regards to the first question, the evidence for or against dissociated linkages between information stores in regards to the second is tenuous at best. We identify deficiencies in the current literature that should motivate and inform the design of future studies.

Keywords

face; voice; name; semantic; hub; familiarity endnote – voice and face

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1. Introduction

The ability to recognize and identify people is a key social function. It is also a complex one, taking inputs from several modalities and bridging an interface between perception, memory and semantic knowledge. Face recognition is its most studied aspect, but is only one of a number of access points to the process of recognizing people. One can identify people by their voice, their name, and other cues such as body habitus, personal belongings, handwriting, gait and body motion (Ardila, 1993; Bruyer, 1990). As little research has been conducted on the latter properties, though, this review will focus on the evidence for identification through faces, voices and names.

Recognition and identification have several facets, ranging from the realization that one has encountered this person before (familiarity) to the retrieval of biographical information about the person, memories of specific interactions with that person, and recollection of their name[1]. Our daily experience furnishes examples of occasions where identification is only partial: for example, realizing that one has seen the face but not knowing where or when, or knowing details about the person while the name eludes recall. To a degree, these facets can be placed in a hierarchy of increasing specificity (Haslam, Cook, & Coltheart, 2001), and are reflected in cognitive models of recognition as a series of processing stages or modules.

Person recognition may be particularly amenable to traditional cognitive modeling as typified by "box-and-arrow" diagrams (Coltheart, 2011). These postulate that a cognitive process occurs through a series of distinct modules, with the output of one operation serving as input for another. In the case of a process like person recognition, in which there is convergence or interaction of information from multiple modalities[2], there are parallel as well as sequential operations. Models may differ in whether the processing in one operation overlaps in time with that of a prior one, or whether information flow is unidirectional or has both feedforward and feedback aspects: ultimately, common to all is the fact that processing involves discrete modules which can function independently of each other.

Important sources of data for such cognitive models have been neurologic disorders. There are two main requirements for the study of modular processing in a neuropsychological context. The first is that, in addition to the final output of the entire process, intermediate outputs of the operations of various modules can be measured, so that one can determine the functional status of individual modules. The second is that functional modules map onto distinct neural structures (Coltheart, 2011). If so, then there should be patients in whom focal lesions have either a selective influence on modules, resulting in classical double dissociations with one module impaired and the other spared, or at least a differential influence, causing non-classical double dissociations with both modules impaired but one more than the other (Sternberg, 2011).

[1]For clarity, we will use recognition as synonymous with familiarity, the realization that one has encountered the stimulus before, while identification will refer to the ability to access information about the person to whom the stimulus belongs.

[2]The term multi-modal is problematic. While faces and voices use the different sensory modalities of vision and audition, names are perceived through either of these modalities. Hence a better term may be 'multi-source'. Nevertheless, we will follow the tradition of referring to face, voice and name as modalities.

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Findings of selective or differential effects provide strong support for the proposal that a process involves distinct operations with specific regional substrates. In the case of person recognition, much of the evidence comes from case reports. However, because of the multiple routes and interactions possible in person recognition, none of the reports provide an exhaustive evaluation of all aspects of identification from faces, names and voices. Furthermore, the logic and assumptions behind inferences made from the data are often vague. The purpose of this review is to provide a critical look at the neuropsychological data, to clarify the functional conclusions possible from the existing cases, and to indicate how future studies may help advance our knowledge. Of course, complementary sources of evidence on person recognition also exist: these are discussed elsewhere, for behavioural studies of the integration of faces, voices and names (O'Mahony & Newell, 2012; Schweinberger, Kloth, & Robertson, 2011), and functional neuroimaging work in healthy subjects (Blank, Wieland, & Kriegstein, 2014; Yovel & Belin, 2013).

1.1 Current models of person recognition

Probably the most influential cognitive model of person recognition (Bruce & Young, 1986) focused on face processing, which is not surprising given that the largest body of neuropsychological evidence on identifying people concerns face perception. The structure of this model borrowed from Hay and Young (1982), as well as models of word and object processing of that era (Nelson, Reed, & McEvoy, 1977; Warren & Morton, 1982). This model had two key features. First, there were separate processing streams for face identity versus other types of facial properties, such as expression and gaze. Second, identity information flowed through a series of stages: after perceptual encoding of the aspects of facial structure relevant to identity, the coded percept was matched to stores of facial memories called ‘face recognition units’, and then followed by access to semantic and episodic information about a person stored in a ‘person identity node’ as well as to their name (Figure 1). In parallel, studies have suggested the existence of functional variants of prosopagnosia, the inability to recognize or identify familiar faces, that correspond to dysfunction at various stages in this model (Barton, 2008; Damasio, Tranel, & Damasio, 1990; de Renzi, Faglioni, Grossi, & Nichelli, 1991; Hécaen, 1981).

This model survives (Young & Bruce, 2011) and continues to influence computational (Bredart, Valentine, Calder, & Gassi, 1995; Burton, Bruce, & Hancock, 1999), neuroimaging (Haxby, Hoffman, & Gobbini, 2000) and neuropsychological studies (Barton, 2008; Davies-Thompson, Pancaroglu, & Barton, 2014). It has been elaborated into more extensive multimodal models of person recognition (Figure 1), by incorporating parallel arms for voice and name recognition (Belin, Fecteau, & Bedard, 2004; Ellis, Jones, & Mosdell, 1997), as well as other cues (Bruyer, 1990). The relation of names to other types of semantic information in this model continues to be debated. Name retrieval has been represented as a stage subsequent to semantic information (Bruce & Young, 1986), a name module parallel to semantic information (Bredart et al., 1995), or merely a subset of semantic information (Burton & Bruce, 1992). In addition, a model incorporating hemispheric lateralization of different modalities has been proposed, with a stream for name recognition lateralized to the left hemisphere and streams for voice and face recognition to the right (Gainotti, 2014). Finally, these box-and-arrow models have been modified to create

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more complex connectionist models to account for various phenomena of face recognition in both healthy populations and those with person recognition disorders (Young & Burton, 1999).

There are two key questions regarding models of person recognition and identification. The first is the locus of familiarity effects, whether this arises in recognition units or at the level of the person identity nodes that either hold or mediate access to identity-specific semantic information. Bruce and Young (1986) initially proposed that the strongest sense of face recognition or familiarity required not just matching of the face to a stored representation of a previously seen face but also subsequent access to identity-specific semantic information. Hence some models assigned face familiarity to the operation of person identity nodes in retrieving identity-specific information about the person to whom the face belongs (Burton et al., 1999; Burton, Bruce, & Johnston, 1990). However, familiarity can have several facets, such as familiarity for the stimulus (face, voice, name) and familiarity for the person to whom the stimulus belongs (Gainotti, 2007; Haslam et al., 2001; Schweinberger & Burton, 2003). In the case of faces, it is possible to isolate stimulus familiarity by probing the ability of a subject to recognize a recently viewed anonymous face, about which they have no other information. Such tests place minimal demands upon access to identity-specific semantic information. Observations that dissociations can occur between familiarity for faces and familiarity for names in some cases of temporal atrophy (Gainotti, Ferraccioli, & Marra, 2010) have led to inferences that familiarity is modality-specific and therefore more likely to reflect operations of recognition units than those of amodal person identity nodes (Gainotti, 2014). This is consistent with other models that propose that familiarity signals arise separately for each route to recognition, voices, faces and names (Farah, O'Reilly, & Vecera, 1993).

The second is the organization of identity-specific semantic information. This is a stage following recognition units. A successful match of the current stimulus to a representation of a previously seen one in recognition units triggers subsequent access to more information about the person. Such semantic information was initially envisaged as consisting of biographic data such as occupation, social relationships, nationality, etc. (Bruce & Young, 1986; Burton et al., 1999). Recent proposals suggest that, in addition to this verbally coded semantic knowledge, which may be localized to the left hemisphere, there are also sensory or “pictorial” forms of semantic knowledge, such as knowing the appearance of someone's face or the sound of their voice, which localize to the right hemisphere (Gainotti, 2014). However, the representations of a person's face or voice are precisely what must be stored in recognition units to generate correct matches between current and past experience. There does not seem to be any reason or evidence to propose that face and voice representations are stored in duplicate, in recognition units and some later sensory semantic units. Hence, until there is evidence to the contrary, we would propose that recognition units *are* the stores of sensory semantic knowledge about people. Indeed, this has been implied in other reports of associative/mnestic forms of prosopagnosia that attribute both the prosopagnosia and accompanying deficits in facial imagery to the loss of stored knowledge of facial appearance (Young, Humphreys, Riddoch, Hellawell, & de Haan, 1994). In our modeling of the data, we will reserve the term semantic information units to refer to verbal biographic

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information, even though the information stored in recognition units can be thought of as modality-specific sensory semantics.

How biographic semantics, names, face representations, and voice representations are linked to each other to create a unitary experience of the person is an important question. This is related to a more general debate about the organization of semantic knowledge, about which there are two main views. The ‘semantic hub’, or “hub and spoke”, model proposes the existence of an amodal or pan-modal semantic hub that binds and mediates access to knowledge about things from different modalities (Hoffman, Jones, & Ralph, 2012; Jefferies, 2013). The ‘distributed-only’ view suggests that the representations of different types of knowledge are located in different cerebral regions and interact directly without mediation through a central hub (Gainotti, 2011). In the field of person recognition, this debate centers around the role and nature of person identity nodes (Figure 2). In some models favoring a ‘distributed-only view’ (Bruce & Young, 1986), person identity nodes are synonymous with stores of identity-specific semantic knowledge, or biographic information about people. In other models, they are configured as ‘person-hubs’ that mandatorily mediate access to that information (Burton et al., 1999; Burton & Bruce, 1993; Gainotti, 2014). The implication for neuropsychology is that damage to a person-hub should result in an inability to link any type of person-related information: hence if a person cannot name the face, they should also fail to name the voice, or to link biographic information to the face, voice or name. In contrast, the distributed-only model would predict frequent dissociations among links. Thus some patients may be able to name the face but not the voice, or vice versa. While such dissociations have been reported, the validity of the inferences in many cases can be questioned on logical grounds.

1.2 Assessing the evidence: the intermediate outputs of cognitive modules

From the above, one can appreciate that successful identification of a person is the final output of a series of cognitive operations. The ability to probe the status of these individual operations independent of the final output of the entire series is key to evaluating the predictions of models in neuropsychological cases. Hence ‘intermediate outputs’ need to be identified: these are responses that can be attributed to the operation at a particular processing stage in the hierarchy. In person recognition, three key stages are a) the perceptual encoding of stimuli, b) the operation of recognition units, and c) the access to and interaction between stores of semantic and sensory information about people.

The perceptual encoding of stimuli is modality-specific, and is usually assessed by the ability to discriminate between stimuli based on their physical differences. The Table lists the types of tests used to assess face and voice perception. For faces, this is usually probed by tests of face-matching, sometimes across differences in lighting or viewpoint to stress sensitivity to three-dimensional facial structure. The Benton Face Recognition Test (Benton, Sivan, Hamsher, Varney, & Spreen, 1983) is often used, though its sensitivity for perceptual deficits has been questioned (Farah, 1990; Gainotti, 2010). More sensitive may be tests of the ability to discriminate differences in facial structure introduced by altering features or their configuration (Barton, 2008; Liu, Pancaroglu, Hills, Duchaine, & Barton, 2014) or other match-to-sample tests, such as the Cambridge Face Perception Test (Bowles et al.,

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2009; Duchaine, Germine, & Nakayama, 2007). On occasion, tests of the perception of facial age, gender or gaze direction have been used as indices of perceptual encoding (Evans, Heggs, Antoun, & Hodges, 1995; Gainotti, Barbier, & Marra, 2003; Gainotti, Ferraccioli, Quaranta, & Marra, 2008; Gentileschi, Sperber, & Spinnler, 1999, 2001) but the logic of this strategy is dubious as these aspects are not directly related to facial identity, and in the case of age and gaze their perception likely depends on different cues (Lai, Oruc, & Barton, 2011) or even use different processing streams (Bruce & Young, 1986; Haxby et al., 2000). For voice encoding, similar discriminative tests have been created to assess matching of voices across different speech segments (Garrido et al., 2009; Hailstone et al., 2011; Liu et al., 2014; Neuner & Schweinberger, 2000; Van Lancker & Kreiman, 1987). While voice and face encoding are specific high-level forms of sensory processing that can be impaired selectively and independent of other visual or auditory processes, there is no evidence of a name-specific encoding mechanism distinct from other language processing. Hence the absence of aphasia is usually taken as sufficient evidence of the ability to encode names.

How do we assess recognition units? Recognition implies the matching of a currently viewed stimulus to a stored perceptual representation, affirming that one has encountered the stimulus before. Hence stimulus familiarity is the logical intermediate output of a successful match at the recognition-unit stage. In the case of faces, familiarity is often measured by presenting subjects with a series of famous or personally known faces and anonymous faces, and asking the subject to indicate which faces are familiar. The same can be done with voices (Garrido et al., 2009; Hailstone, Crutch, Vestergaard, Patterson, & Warren, 2010; Neuner & Schweinberger, 2000). However, there are potential problems with using celebrities or family members as test stimuli. First, there is the practical difficulty of determining whether patients and control subjects have had equivalent exposure to the stimuli. Second, there is the theoretical issue of what stage of person recognition they probe. As mentioned above, familiarity can have several facets, such as familiarity for the stimulus and familiarity for the person to whom the stimulus belongs (Gainotti, 2007; Haslam et al., 2001): the rich semantic associations of most known faces means that the two may be confounded. To stress stimulus familiarity rather than person familiarity, it may be better to test familiarity for recently viewed faces of anonymous people, about whom one has no other information. Examples include the Warrington Recognition Memory Test (Warrington, 1984) and the Cambridge Face Memory Test (Duchaine & Nakayama, 2006). The same can also be done for voices (Liu et al., 2014) and names. These probe the ability to form and store a stimulus representation and later retrieve it. A potential issue with this method, though, is whether the limited experience during learning of new stimuli is sufficient to create the type of structural representation envisioned in recognition units, capable of supporting recognition across natural variations, such as viewpoint, expression, and lighting for faces. Learning and testing with several different samples or images of the stimulus may help, as is done with the Cambridge Face Memory Test. Also, there is evidence that the human visual system has substantial capacity to generalize from even a single view of a face to support recognition under new viewing conditions (Moses, Ullman, & Edelman, 1996).

Beyond the recognition unit stage is the ability to access other information from the recognized stimulus. Most often, this involves examining the links between stimulus-

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specific recognition units and semantic information by asking the subject to provide semantic information about the stimulus (face, voice, or name). Damage to a link can be inferred if this cannot be done despite integrity of the stages being linked. Thus, disruption of a link between face recognition units and semantic stores is indicated by 1) inability to provide biographical information about a face, despite 2) intact face familiarity that confirms integrity of the face recognition units, and despite 3) intact ability to provide semantic information when given the voice or name, confirming integrity of semantic stores. Besides linkages from sensory representations to semantic stores, it is also possible to probe linkages between sensory representations by asking the subject to match a voice to a face, or vice versa. Thus, there are bi-directional linkages between voices, faces, names and semantic information: to be specific, we will indicate in this review the specific linkages tested in each report.

1.3 Assessing the evidence: logical inference from the data

In addition to the outputs of modules, it is important for clarity's sake to consider the logic of the inferences made from neuropsychological evidence in any hierarchical model, particularly because in none of the cases to be discussed are all components of person identification tested. We illustrate this with a simple diagram of a hierarchical model with two sequential modules (Figure 3).

First, proof of damage to a module (e.g. module B) requires not only evidence of impaired output of that module but also integrity of the preceding operations (e.g. module A) that provide input to that module (Figure 3.i). Thus, dysfunction of face recognition units requires not only evidence of impaired face familiarity but also proof of intact encoding of faces, as reflected in normal perceptual discrimination of faces. In several cases to be discussed, failure to assess the function of the preceding module limits the utility of the evidence.

Second, a corollary inference is that if module A is dysfunctional, then impaired outputs from module B may be most parsimoniously attributed to the degraded input to module B from module A (Figure 3.ii). One cannot make any conclusion about the integrity of the operations in module B unless there is an alternate input that bypasses module A. Thus impaired face familiarity does not imply damage to face recognition units, if it merely reflects poor perception of faces because of face-encoding problems. This difficulty may be circumvented by using face imagery tasks as an alternative input to probe the status of face recognition units (Barton & Cherkasova, 2003; Barton, 2008).

A similar caution is required regarding evidence about the integrity of linkages (Figure 3.iii). A failure to attach names to faces is only evidence of a dysfunctional face-to-name linkage if face and name representations are intact, as shown by normal familiarity for both faces and names, as loss of either face or name recognition units can account for problems naming faces.

On the other hand, one might infer reasonably from normal output of one module that upstream modules are also intact (Figure 3.iv). Thus if a subject seeing a face can provide the name and semantic information about the person, it is reasonable to assume that

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familiarity for faces is normal and that face recognition units are operating normally, even if face familiarity is not formally tested. This is reflected in the scoring logic of other reports (Drane et al., 2013) that give credit for familiarity when a subject can name a face. Likewise intact familiarity can be considered proof of adequate perceptual encoding of faces. The ability to link two types of person information also likely implies integrity of those information stores: thus, if one can match voices to faces, then voice and face sensory representations must be intact.

Finally, it needs to be stressed that these logical inferences are most appropriate to stage models, in which information flow is unidirectional (i.e. feed-forward only). In interactive models there is feedback as well, so that a module receives input from not only upstream but also downstream operations. In this situation the intermediate output of a module may be degraded when there is dysfunction in downstream modules. The result would most likely be a non-classical dissociation, with reduced outputs of both modules but less severe from the one that is intact (Figure 3.v). For example, this could account for the finding that patients with right anterior temporal lobe damage who have severe impairments in face familiarity and face imagery, indicative of dysfunction of face recognition units, also have deficits in face perception (Barton, Zhao, & Keenan, 2003), but less severe than those seen in patients with fusiform lesions (Barton, 2008). There is also other neurophysiologic (Freiwald & Tsao, 2010) and neuropsychological (Busigny et al., 2014) evidence whose ability to support a view of bi-directional flow in face processing can be debated.

2. A review of neuropsychological cases

To create the following sections we performed a systematic review of all reports known to us that evaluated the ability of patients to recognize or identify people from at least two sources of information (e.g. face, voice). Our focus was primarily on reports for individual patients, most with acquired disorders, though we finish with a review of group studies, most of which were performed in patients with epilepsy. In these following sections we will refer to cases by the identifiers used in the original articles.

To facilitate understanding of the nature of the evidence compiled in each case, we will illustrate its results using the model diagram in Figure 2, “the distributed-only view”. This does not imply a preference for that view over the person-hub model; rather, it is chosen as the easiest and most unbiased means of showing the empiric data. If the data were consistent with the person-hub model, this would be evident as impaired linkages between different recognition units (e.g. face to voice) and between recognition units and semantic stores (e.g. voice to semantic), which are depicted in red, while the recognition units and semantic store are themselves intact (depicted in green.) The specifics of the tests used to determine the status of a module or linkage are given in Tables 1-3.

2.1 Case studies: familiarity

Cases with impaired familiarity provide the opportunity to clarify two points: first, whether familiarity is dissociable between modalities, consistent with the assertion that it arises from operations at the level of recognition units (Gainotti, 2014), and second, if so, whether modality-specific familiarity is lateralized.

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On the logical grounds described above, though, the data of patients with impaired perceptual encoding cannot address questions about downstream familiarity effects. Hence it is necessary to exclude cases in which perception was either impaired or not assessed (Figure 4). Thus we excluded cases with impaired face discrimination, such as case 31 (Neuner & Schweinberger, 2000), FG (Joubert et al., 2003), and R-IOT1, R-IOT4, L-IOT2, B-IOT2, and R-AT5 (Liu et al., 2014). A number of subjects had normal scores on the short form of the Benton Face Recognition test or a comparable face matching test, but were impaired on a facial age discrimination test. Even though one can argue that discriminating facial age may be irrelevant to identity processing, and that there is evidence that age representations depend on different structural properties than identity representations (Lai et al., 2011), such a finding nevertheless raises doubt about the status of perceptual encoding. Thus, to err on the conservative side, we represent this type of finding as a borderline result. The subjects in question were Maria (Gentileschi et al., 1999), Emma (Gentileschi et al., 2001), and VL (Gainotti et al., 2010). For VL, age discrimination became impaired at a later assessment after it had been normal at the first visit when face familiarity was found to be impaired. We also excluded cases with impaired voice discrimination, such as case 1 (Neuner & Schweinberger, 2000), B-ATOT2 (Liu et al., 2014) and KH (Garrido et al., 2009), who was impaired only on discriminating between more difficult noise-vocoded speech samples.

For the same reason, reports of impaired face or voice familiarity that did not assess the perceptual encoding of faces and voices are not of value, as one cannot rule out the possibility that loss of stimulus familiarity is due to impaired perception of the stimulus. This applies to the studies of MT (Nakachi et al., 2007), LT (Kapur, Ellison, Smith, McLellan, & Burrows, 1992), and DR (Eslinger, Easton, Grattan, & Van Hoesen, 1996) which reported impaired face familiarity but did not assess face perception. It also applies to studies that assessed face perception but failed to assess voice perception adequately or at all, despite their reported impaired familiarity for voices. This includes CD (Gainotti et al., 2008), MD (Busigny, Robaye, Dricot, & Rossion, 2009), case 26 (Neuner & Schweinberger, 2000) and Maria (Gentileschi et al., 1999). Emma's results for voices could be challenged on the basis that the integrity of voice perception was indirectly inferred by her ability to make binary classifications of the age and gender of voices (Gentileschi et al., 2001).

The remaining cases allow us to examine if familiarity is dissociable between modalities. Among those with left-dominant lesions (Figure 5), almost all had normal familiarity for faces, with the exception of LP (De Renzi, Liotti, & Nichelli, 1987). Familiarity for names was also normal in case 24 (Neuner & Schweinberger, 2000) and MA, who is shown in Figure 6 (Thompson et al., 2004). However, EK (Eslinger et al., 1996) and M (Snowden, Thompson, & Neary, 2012) showed a dissociation between normal face familiarity and impaired name familiarity, while StG had intact face familiarity and a borderline deficit for name familiarity (Gainotti et al., 2010). Voice familiarity was assessed in only case 24 (Figure 4), and was impaired (Neuner & Schweinberger, 2000), and therefore dissociated from his normal face and name familiarity.

Among cases with right-dominant lesions, many had intact face perception with impaired face familiarity (Figure 5). Some also showed parallel deficits for name familiarity, such as

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case 26 (Neuner & Schweinberger, 2000) (Figure 4), JP (Thompson et al., 2004), KS (Ellis, Young, & Critchley, 1989) and BD (Hanley, Young, & Pearson, 1989). Similarly, others showed parallel deficits for voice familiarity with intact voice perception, such as case 37 (Neuner & Schweinberger, 2000), QR and KL (Hailstone et al., 2010). In these three, name familiarity was also impaired in KL but spared in QR and case 37. A double dissociation between face and voice familiarity is evident in other cases. Case 22 (Neuner & Schweinberger, 2000), R-AT2 and R-AT3 (Liu et al., 2014) had impaired face familiarity with intact voice familiarity, while case 5 and case 30 (Neuner & Schweinberger, 2000) had the reverse, intact face familiarity with impaired voice familiarity. Name familiarity was normal in all of these patients except for case 22.

Finally for cases with bilateral lesions lacking a clear asymmetry, case 13 (Neuner & Schweinberger, 2000) and B-AT1 (Liu et al., 2014) showed impairment in familiarity for all three stimuli, faces, voices and names; however B-AT2 showed impaired familiarity for faces and voices but intact familiarity for names (Liu et al., 2014), and hence a performance pattern similar to that of QR (Hailstone et al., 2010).

Thus, double dissociation can be demonstrated in familiarity judgments between all three types of stimuli (face, voice, and name). While there are some cases in which face, voice and name familiarity were all affected, the best example being KL (Hailstone et al., 2010), the right and left lesion data show that all three types of familiarity can be selectively impaired (although a case with impaired name familiarity and intact voice and face familiarity has yet to be reported).

Regarding hemispheric specialization, it is clear that familiarity for faces and voices is far more affected by right- than left-dominant lesions. While left-dominant lesions almost uniformly impair familiarity for names, right-dominant lesions also do so in about half of cases. It is not clear whether this implies that either hemisphere can be responsible for name recognition, or merely reflects the fact that these lesions are not strictly unilateral but rather asymmetric. In only KS (Ellis et al., 1989) is the pathology, a temporal lobectomy, definitely unilateral, but even here the pre-existing condition of epilepsy could be associated with anomalous lateralization.

The fact that face, voice and name familiarity can be dissociated from each other is consistent with their reflecting the operations of independent recognition-unit modules specific to each modality, as depicted in most cognitive models (Belin et al., 2004; Ellis et al., 1997; Gainotti, 2014). This implies that a familiarity deficit in which a patient cannot recognize people from two or more modalities does not constitute a disorder with a single underlying dysfunction, but one in which multiple deficits co-exist. Thus this may be better termed a multimodal person-recognition syndrome, rather than a disorder. This is consistent with the current neuroimaging evidence, which shows that while voices and faces both activate regions in the anterior temporal lobes, these are anatomically distinct from each other (Belin, Zatorre, Lafaille, Ahad, & Pike, 2000; Joassin et al., 2011; Shah et al., 2001).

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2.2 Case studies: identification

Beyond recognition units, useful data on the ability to link name, voice and face stimuli to each other and to semantic information about persons are sparse. First, many demonstrations of impaired linkages involve patients who have impaired familiarity. Inability to recognize the stimulus can account for downstream failures to link semantic or other information to that stimulus. Thus the subjects with impaired face familiarity after right-dominant lesions, as depicted in Figure 5 and discussed in the preceding section, are uniformly unable to name or provide semantic data about faces when tested for these abilities. Similarly, those with impaired voice familiarity cannot link voices to names, faces or semantic data, such as CD (Gainotti et al., 2008) (Figure 4), QR and KL (Hailstone et al., 2010) (Figure 5), and those with impaired name familiarity cannot provide semantic data about those named, such as LT (Kapur et al., 1992) (Figure 4), EK (Eslinger et al., 1996), M (Snowden et al., 2012), LP (De Renzi et al., 1987), JP (Thompson et al., 2004), KS (Ellis et al., 1989), and BD (Hanley et al., 1989) (Figure 5). Impaired name familiarity can also account for difficulties matching names to faces and vice versa in LP, and further compounded by impaired familiarity for faces too in EK. StG was not as good with name familiarity as with face familiarity, though not quite at the threshold for impairment (Gainotti et al., 2010).[3]

Second, a number of studies that report inability to access semantic data from voices or names or to link voices to faces or names failed to establish intact familiarity for faces, voices and/or names (Figure 6, top row). These include reports on PV (Boudouresques, Poncet, Cherif, & Balzamo, 1979), VH (Evans et al., 1995), CO (Gainotti et al., 2003), and JT (Gorno-Tempini et al., 2004).

This leaves four right-dominant cases of interest (Figure 6, middle row). Patient G was not able to produce semantic information to a name despite intact name familiarity (Snowden et al., 2012). G also could not produce semantic information linked to faces, but face familiarity was impaired, limiting the value of this case regarding the question of dissociations in linkages. RFR (McCarthy & Warrington, 1992; Warrington & McCarthy, 1988) had difficulty with memory for recently encountered faces as assessed by the Warrington Recognition Memory Test, yet scored normally when choosing the famous face or name from an array with anonymous distractors. Despite his seemingly intact face and name familiarity, RFR could name only one or two famous faces, and could not sort either famous faces or names chronologically (Warrington & McCarthy, 1988). However, in a second report, RFR could provide semantic information for 21 of 24 names but only for 7 of 24 faces (McCarthy & Warrington, 1992). One could argue then that RFR has sufficiently intact face familiarity (despite his trouble with the Warrington Recognition Memory Test) and has at least a non-classical dissociation with more trouble accessing semantic information from faces than from names. TG (Haslam et al., 2001) was assessed on a battery with questions of increasing semantic specificity. TG had significant familiarity with faces but his ability to provide any semantic information was poor. His ability to name faces was surprisingly good for famous people but non-existent for family and friends. In contrast, he

[3]In some group studies (Drane et al., 2013) this secondary impact of impaired familiarity on naming or identification is acknowledged, and the latter are assessed only on items that subjects indicate are familiar.

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had not only intact name familiarity but could provide semantic information about names, failing only at the most specific level. The patient described in Mendez and Ghajarnia (2001) scored normally for familiarity with 48 famous faces but was only able to provide identifying information about 2 of 24 famous faces, which contrasted with the ability to provide semantic information about all of 24 famous names.

Among the three left-dominant cases of interest (Figure 6, bottom row), DBO had intact face familiarity but trouble naming or providing semantic information about faces; however, it was stated that he could provide biographical information when given people's names (Anaki, Kaufman, Freedman, & Moscovitch, 2007). Although NG's report provides little actual data, he apparently showed interesting bidirectional dissociations: when given names she could point to the correct faces and provide semantic information, but when given faces or semantic information she could not retrieve the name (Geva, Moscovitch, & Leach, 1997). However, few details are given in this case and neither name nor face familiarity were assessed. Normal familiarity for faces and names was shown in MA, who showed the same bidirectional asymmetry, with inability to name any face but 88% accuracy on matching faces to spoken names (Thompson et al., 2004). MA scored better than 90% in sorting names by occupation or other subordinate information such as nationality or living status, but had more difficulty doing the same for faces, scoring 75% for occupation and 83% for subordinate knowledge.

Finally case ME with non-localizable vasculitic damage on imaging (De Haan, Young, & Newcombe, 1991) displayed normal matching of faces and normal judgments and ratings of familiarity for famous versus anonymous faces as well as names; however she was impaired in naming faces and in providing biographical information for either faces or names. This could be consistent with damage to either linkages from sensory representations to semantic stores, or damage to the semantic stores themselves.

To summarize, the right-dominant cases TG, RFR and the Mendez patient all present a similar picture, of difficulty accessing names or semantic information from faces, with normal or much better preserved ability to access semantic information from names. Interestingly MA and DBO, with left dominant lesions, had similar patterns. The ability to access faces from names was not tested in TG, RFR or the Mendez patient, but was preserved in MA and reportedly NG, despite their inability to name faces.

To complete the double dissociation, a case with normal access to semantic information from faces with impaired access from names is needed. So far, StG is the only such candidate. He showed a ‘slight advantage in drawing semantic information from faces...than from names’ (p107). However, name familiarity was less than face familiarity, though in the normal range, and he was impaired in producing names to either faces (31/45, normal >31.7) or semantic descriptions (27/45, normal >33.3). Hence there is uncertainty as to whether some dysfunction of name recognition units can account for the slightly poorer performance in accessing semantic information from names.

Regardless, as noted by others (Haslam et al., 2001) dissociations such as those seen in TG, RFR, the Mendez case, and MA present a challenge for a person-hub model. Such a model

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would predict equivalent difficulty in accessing any type of identity-specific information from any other type, if the person-identity-node is damaged. It may be possible to reconcile these observed dissociations with the person-hub model by postulating that it is not the person-identity-node that is damaged but the connections (‘spokes’) between various types of information to this hub that are affected. However, the dissociations in this type of scenario are difficult to distinguish from the patterns of damage in a distributed-only model.

2.3 Item concordance in case studies

An important but often neglected issue that is relevant to the debate about semantic hub versus distributed-only models of semantic processing is item concordance. If a person-hub exists, then not only should one find deficits of similar severity in identifying names, voices and faces at a subject level, but the results should agree for individual test items. Thus, if one cannot identify one's mother by her face, one should also not be able to do so by her voice, by her name, or by her biographic information.

In subject KS, who had a right anterior temporal lobectomy, the concordance between identification from faces and names was significant but weak (Ellis et al., 1989). On the other hand, the faces ME could name were also the ones for which she could provide semantic information (De Haan et al., 1991). Item-by-item comparisons showed better familiarity and identification for faces than for names in patient M, with predominantly left temporal atrophy, and the converse in patient G, with mainly right temporal atrophy (Snowden et al., 2012). Identifying famous faces and identifying famous names was correlated in a group with right or left temporal lobe atrophy (Snowden, Thompson, & Neary, 2004). On an individual-subject basis, the concordance between producing semantic information for faces versus doing the same for names was significant but far from perfect in all 10 patients in whom this could be assessed (Snowden et al., 2004). The concordance for familiarity judgments was worse, with significant concordance between faces and names in only 5 of 11 patients.

Others have stated that only weak or partial concordance between the retrieval of biographic information from faces and names presents a challenge for the person-hub model (Snowden et al., 2012). However, the impairment of name and/or face familiarity in all three of the studies above limits the conclusions that can be drawn from the partial concordance between modalities in semantic access. If familiarity arises in modality-specific recognition units, then discordance in semantic access may simply reflect downstream effects of variable damage to recognition units. Ideally, evidence for damage to an amodal semantic hub would be perfect item-by-item concordance in linking stimuli of different modalities to semantic information (or to each other) in a subject with intact familiarity for each stimulus. No such evidence yet exists.

3. Group studies

Although most of the neuropsychological data are derived from cases, it is worth considering the contribution of group studies (Figures 7 and 8), most of which have been performed on patients with temporal lobe epilepsy. Some included only nonsurgical patients (Benke, Kuen, Schwarz, & Walser, 2013; Seidenberg et al., 2002) and some only post-

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operative patients (Crane & Milner, 2002). Others included both patients who had had surgery and those who had not, with some analyzing these two groups separately (Drane et al., 2013; Glosser, Salvucci, & Chiaravalloti, 2003), and others not (Viskontas, McAndrews, & Moscovitch, 2002). All of these studies have focused more on recognition and identification from face stimuli, with less data on processing names or voices.

There is agreement that left temporal lobe surgery does not impair familiarity for faces, whether tested with famous faces (Drane et al., 2013; Glosser et al., 2003; Seidenberg et al., 2002; Viskontas et al., 2002) or recently viewed anonymous faces (Crane & Milner, 2002; Glosser et al., 2003), but does reduce the ability to name famous faces (Drane et al., 2013; Glosser et al., 2003; Seidenberg et al., 2002; Viskontas et al., 2002). Both of these observations have also been made in patients with left temporal epilepsy without surgery (Benke et al., 2013; Viskontas et al., 2002), although the naming defect is less severe than in those who have had surgery (Drane et al., 2013; Glosser et al., 2003).

Whether left temporal lobe surgery impairs the ability to access semantic information about a famous face is where disagreement arises. However, this may be related to methodological differences. The three studies that reported normal production of semantic information about a face (Drane et al., 2013; Glosser et al., 2003; Seidenberg et al., 2002) gave credit for either giving the name or a verbal description about the occupation or reason for fame. In the study that reported reduced semantic information about faces in non-surgical patients, naming did not contribute to a correct score for semantic information: this was judged by answers to three specific questions, about country of origin, occupation, and one unique fact about the person (Benke et al., 2013). Likewise, Viskontas et al. (2002) required subjects to give a forced-choice response to a specific semantic question if they did not volunteer the information. While they did not find a statistically significant reduction, their results suggest borderline low performance with high variability in their patients.

All studies agree that right temporal lobe surgery impairs familiarity for faces (Crane & Milner, 2002; Glosser et al., 2003; Seidenberg et al., 2002; Viskontas et al., 2002). Two studies of patients with right temporal lobe epilepsy before surgery also reported some mild impairments in face familiarity (Benke et al., 2013; Glosser et al., 2003), but another did not (Drane et al., 2013). One study using the Benton Face Recognition Test also found mild problems in perceptual discrimination of faces, before or after surgery (Glosser et al., 2003), but another used this test to exclude subjects with perceptual deficits (Drane et al., 2013), while a third study of post-surgical patients (Crane & Milner, 2002) claimed intact perception based on age and gender judgments on the Mooney Closure test, which can only be regarded as a very indirect probe of perception of facial identity. Regardless, there is also general agreement that, likely consequent to impaired face familiarity, post-surgical patients have a reduced ability to name faces (Glosser et al., 2003; Seidenberg et al., 2002; Viskontas et al., 2002) or to provide semantic information about faces (Glosser et al., 2003; Seidenberg et al., 2002), with the Viskontas et al. (2002) study again suggesting borderline performance for the latter. One study found reduced naming of faces when all faces were included, but normal performance when scoring included only faces that subjects indicated were familiar, confirming that apparent naming deficits can be a secondary consequence of reduced familiarity for faces (Drane et al., 2013). In non-surgical patients, the more modest deficits

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in familiarity surprisingly did not preclude the ability to achieve normal scores for semantic information from faces in two studies (Benke et al., 2013; Glosser et al., 2003) but did in a third (Drane et al., 2013): this illustrates some of the difficulty in interpreting pooled group results rather than data from individual cases.

Apart from faces, only one of the above studies of epileptic patients examined the processing of names (Viskontas et al., 2002). While this study acknowledged a possible ceiling effect on their name familiarity task, they found that neither right nor left temporal lobe surgery impaired the familiarity of famous names, but that both lesions reduced the ability to access biographical information from names. As mentioned above, the ability to provide such information for faces appeared to be borderline in both groups also.

Three group studies of non-epileptic patients provide additional results. First, in a study of war trauma (Newcombe, Haan, Ross, & Young, 1989), a group of 12 subjects with right hemispheric lesions took longer to make familiarity judgments about famous versus anonymous faces, while a group of 12 with left-sided lesions took longer to make such judgments about names. However, the encoding stage of face processing was not assessed: perceptual testing was limited to acuity and contrast sensitivity, an exclusion of cataracts and glaucoma, and a face decision task using drawings with scrambled features performed by about half of the subjects. Second, a study of semantic dementia contrasted 10 patients with right more than left temporal atrophy and 4 with the converse (Snowden et al., 2012). While both groups showed reduce name and face familiarity, familiarity of names was more reduced in those with left-dominant atrophy, and familiarity for faces in those with right-dominant atrophy. Both groups were impaired in providing semantic information for either names or faces, but this was again more severe for faces in the right group and more severe for names in the left group. Both groups were equally severely impaired in naming famous faces. As for voices, another report of semantic dementia with many of the same patients of the previous study cited above found no difference between the right and left groups in familiarity judgments, naming or the access to semantic information from voices (Hailstone et al., 2011).

4. Conclusions and future directions

Based on the above evidence, it seems reasonable to conclude that familiarity for faces, names and voices can be affected independently, that left-sided lesions can selectively impair name familiarity alone, while right-sided lesions can selectively affect either face or voice familiarity alone, although name familiarity can occasionally be affected along with either face or voice familiarity. This dissociability is consistent with the assertion that familiarity reflects the operation of face, voice and name recognition units (Gainotti, 2014). Furthermore, the finding that the prosopagnosic pattern of preserved face encoding with impaired familiarity is found with right anterior temporal lesions (Barton, 2008; Liu et al., 2014) suggests that face recognition units are located in the anterior temporal lobe, despite others' suggestion that face recognition units may be located in the fusiform gyrus (Rotshtein, Henson, Treves, Driver, & Dolan, 2005; Schweinberger & Burton, 2003).

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However, the major weakness in current studies is the variability in the quality of evidence for intact processing at the preceding level of perceptual encoding of the stimulus. Studies of face processing overwhelmingly rely upon the Benton Face Recognition test, which is not sensitive to deficits in face discrimination (Farah, 1990; Liu et al., 2014) (Table). Other tests such as the Cambridge Face Perception Test or probes of the perception of facial configuration, which correlate with the status of the fusiform face area in acquired prosopagnosia (Barton, Press, Keenan, & O'Connor, 2002; Liu et al., 2014), may prove more useful. It would be important to find supportive evidence that whatever test is used to replace the Benton Face Recognition Testactually does probe the structural encoding stage in the cognitive models (Bruce & Young, 1986): that is, that it assesses the type of perceptual processing that is required to support face identification. For voice perception there are no standard tests. Dissociations between apperceptive deficits in voice and face processing are logical and expected: dissociations in familiarity judgments arising at the level of recognition units can only be believed if it can be shown that these are not inherited from effects in preceding perceptual processing.

Regarding the second issue, of dissociability between the various linkages between the different sensory or semantic representations about people, the evidence is much more sparse. There is some evidence for better access to semantic information from names than from faces in three patients with right-dominant lesions, RFR (McCarthy & Warrington, 1992; Warrington & McCarthy, 1988), TG (Haslam et al., 2001) and the patient of (Mendez & Ghajarnia, 2001). Among the few patients with left-dominant lesions, two (NG, MA) may have shown an interesting bi-directional dissociation, with more difficulty generating names for faces they were shown than matching faces to names they were provided (Geva et al., 1997; Thompson et al., 2004).

Many other cases that examined linkages were disqualified because of impaired familiarity (Figure 5). If one accepts that familiarity indexes the function of recognition units, then logically speaking, cases with impaired familiarity cannot inform us about the status of linkages from or to those recognition units. If one has no face representations, then it is expected that one would be unable to either name faces or put a face to a name, for example. Hence, in future reports, evaluation of the familiarity of faces, names and voices should be an important first step before evaluating further identification processes. A second requirement is a thorough evaluation of as many linkages as possible between faces, names, voices and semantic information. This can be challenging, as given the bidirectional possibilities, there are at least twelve different linkages to be probed. To date, the maximum number of linkages probed in a single case is eight in CO (Gainotti et al., 2003), though this report was marred by failure to assess the familiarity of voices and names. This leaves the most comprehensive assessment as that of QR and KL, which included familiarity assessments of voice, name and face, along with linkages from voice to face, name and semantic information, linkages from face to name and semantic information, but failed to test any linkages emanating from names (Hailstone et al., 2010).

Finally, an important but often neglected test of the semantic hub model is inter-modality concordance for individual items. Not only should the patient show equivalent impairments in various linkages at the test level, but also at the test-item level. If the semantic hub model

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is correct, then if a subject fails to identify a specific relative or celebrity through one modality, they should also fail to identify them by any other modality, or make any linkage concerning this person. Currently, the only studies that evaluated inter-item concordance were in patients who had impaired familiarity, which means that these results may not address the issue of linkages between forms of information about people.

In closing, we should also acknowledge that there may be difficulties in obtaining neuropsychological evidence that definitively distinguishes between the person-hub and distributed-only model. Dissociations in linkages may support the distributed-only model, but could be explained by disconnectionist damage to the ‘spokes’ that connect information stores to the person identity node in a hub model. Conversely, uniform degradation of all linkages may occur with diffuse damage in a distributed-only model. Consistent patterns across numerous patients with similar anatomic lesions may increase the plausibility of conclusions, but the rarity of these patients presents a challenge in this regard. Ultimately, convergent evidence from other types of studies may be required to support conclusions from patient-based data.

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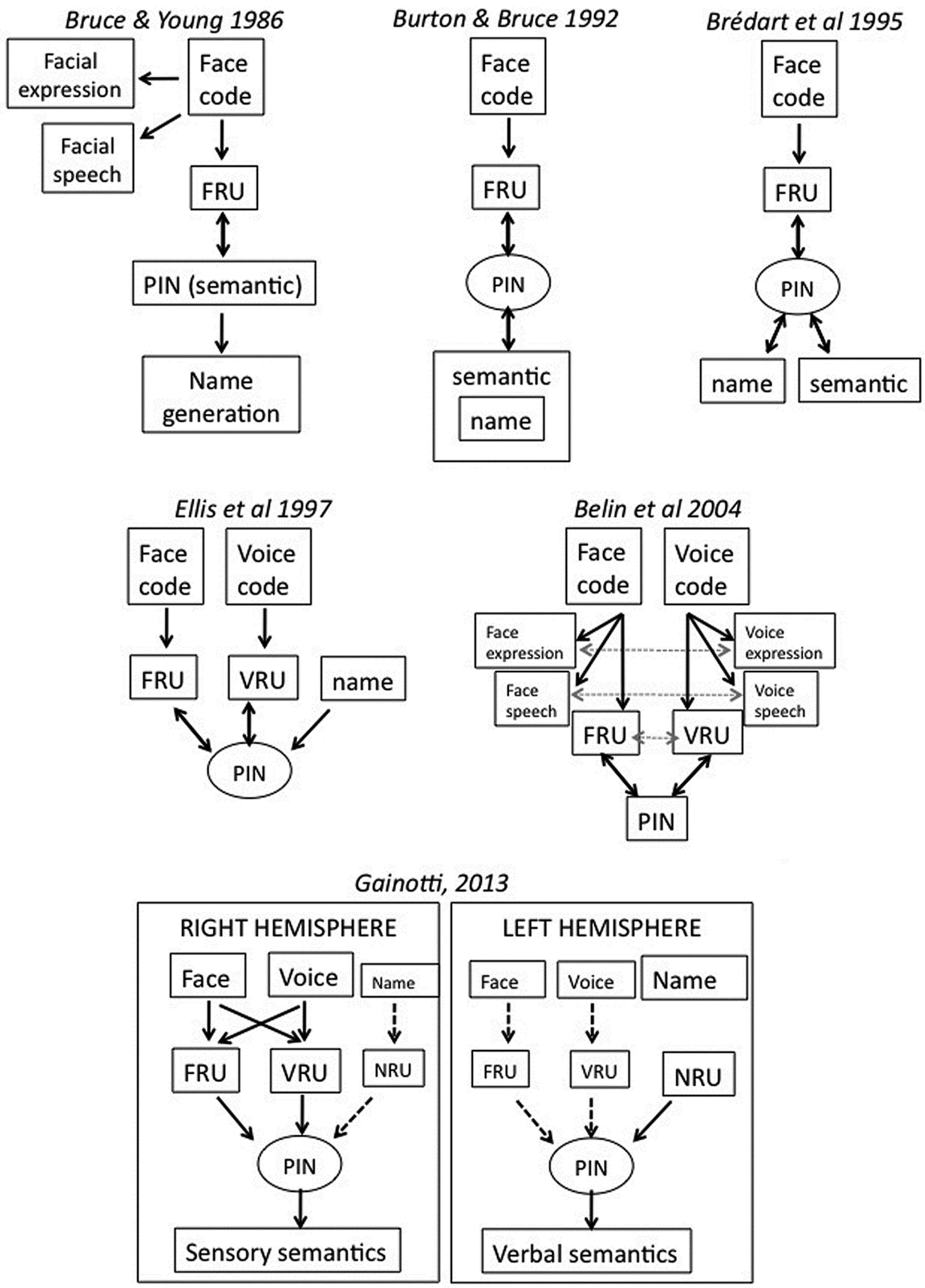

Figure 1.

Cognitive stage models of person identification. In Bruce and Young (1986), perceptual face encoding is followed by matching to a representation of previously seen face in the face recognition unit (FRU), which leads to access to semantic information in a person identity node (PIN) and generation of the name. In Burton and Bruce (1992) the PIN is an amodal hub mediating access to semantic stores, of which the name is part, while in Brédart et al (1995) names are a separate information store. Ellis et al (1997) and Belin et al (2004) added a parallel route for identification from voices. Gainotti (2013) proposed hemispheric differences, with face and voice processing lateralized to the right and names to the left, as well as separate semantic stores for sensory and verbal information. NRU = name recognition unit, VRU = voice recognition unit.

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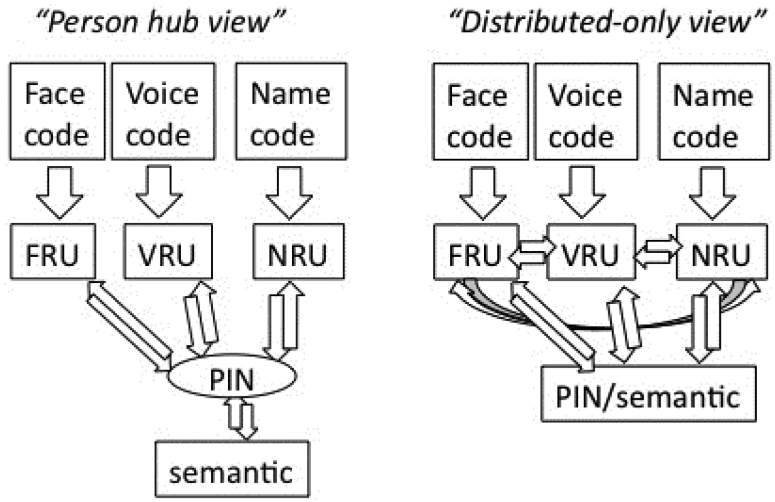

Figure 2.
Models of linkages between sensory and semantic information. In the person-hub model, linkages are mandatorily mediated by the PIN (person identity node) and are conceptualized as spokes emanating to and from this hub. In the distributed-only model the PIN is a store of verbal semantic knowledge and not a hub, and bi-directional linkages pass directly between the sensory information residing in different recognition units as well as the PIN.

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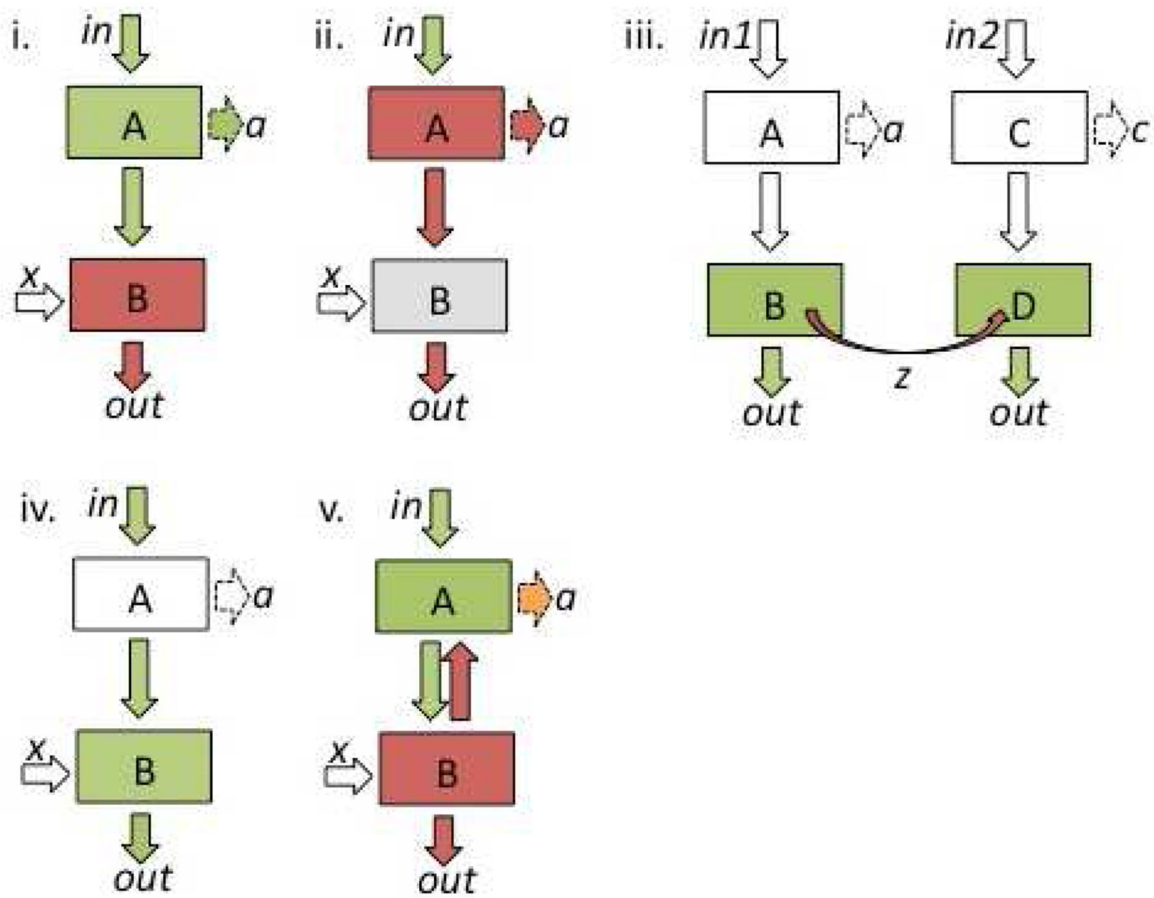

Figure 3.

Logical inference in a 2-stage cognitive model. Green indicates intact function, red indicates impaired function, and orange partial function. i) Impaired output (*out*) can only imply damage in module *B* if module *A* is intact as shown by normal intermediate output *a*. ii) Conversely, impaired output (*out*) does not allow any conclusion about the integrity of module *B*, which is therefore shaded an ambiguous grey, if module *A* is dysfunctional, as shown by impaired intermediate output *a*, unless one can provide an alternative input *x* to module *B* that bypasses module *A*. iii) inability to link the information of modules *B* and *D* can only be considered as evidence of disrupted linkage *z* if modules *B* and *D* are known to be intact. iv) If the output (*out*) from module *B* is normal, then one can infer that module *A* is also intact, even if its intermediate output *a* is not assessed. v) In an interactive model with feedback as well as feedforward connections, if module *B* is impaired, intact module *A* may have a degraded intermediate output *a* if it uses not only feedforward input (*in*) but also feedback information from module *B*.

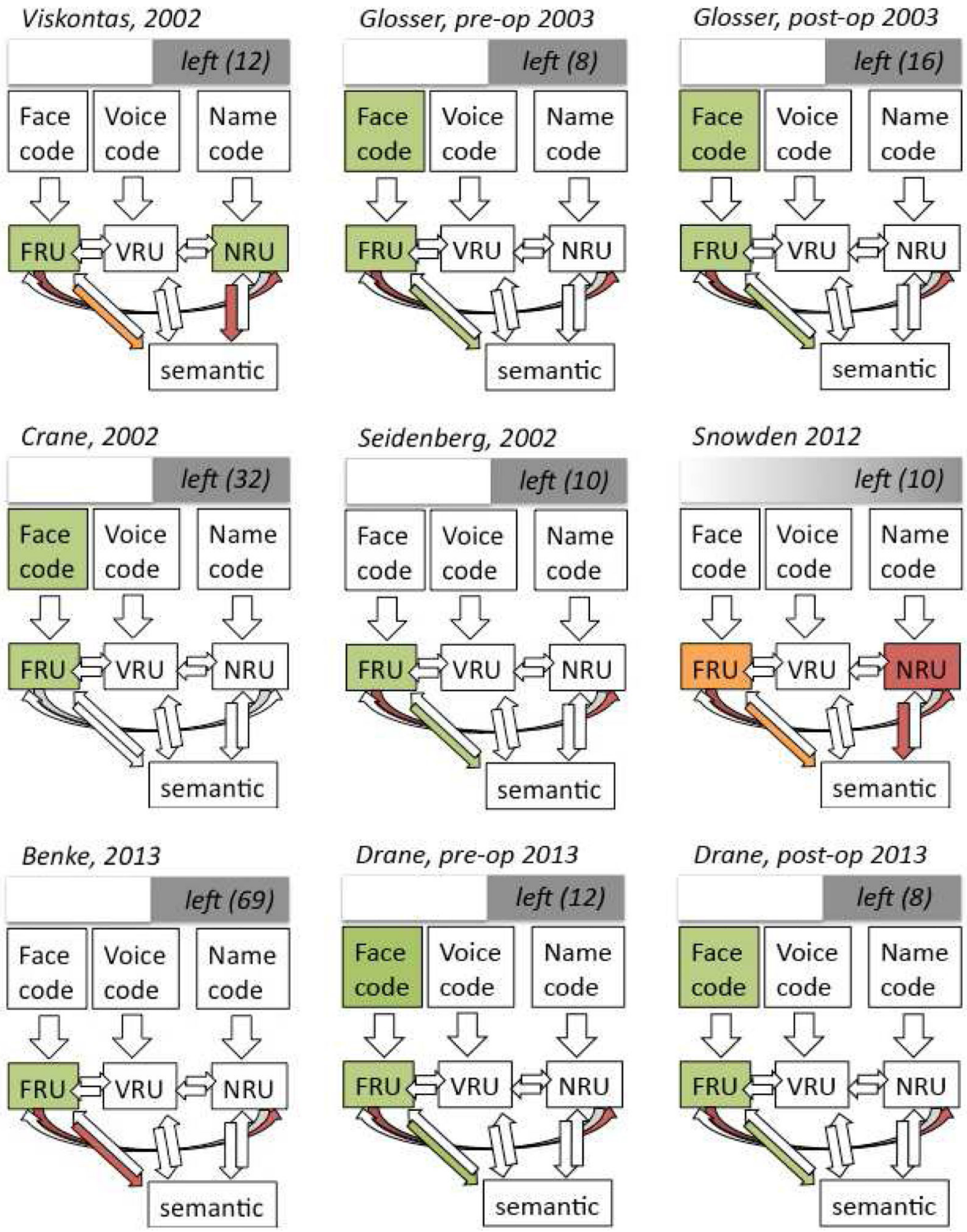

Figure 4.

Excluded cases. Green indicates reported normal function, red indicates impaired function, and orange borderline function. Light green indicates normal results and pink indicates abnormal results on tests that may not be adequate to evaluate the intermediate output of a module. The grey zone in the top bar indicates the lesion side, with distinct grey and white halves indicating unilateral lesions, and graded shading indicating asymmetric lesions that may not be strictly unilateral. For patients of Neuner and Schweinberger (2000), the stippling on the less affected side indicates uncertainty about whether the lesion is strictly unilateral, as information about the pathology in each subject was not given. Top two rows

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show cases in which demonstrated impairments in perceptual encoding invalidate observations of dissociations at the recognition units or later. Bottom two rows show cases in which proof of intact perceptual encoding preceding a reportedly dysfunctional recognition unit is lacking or inadequate.

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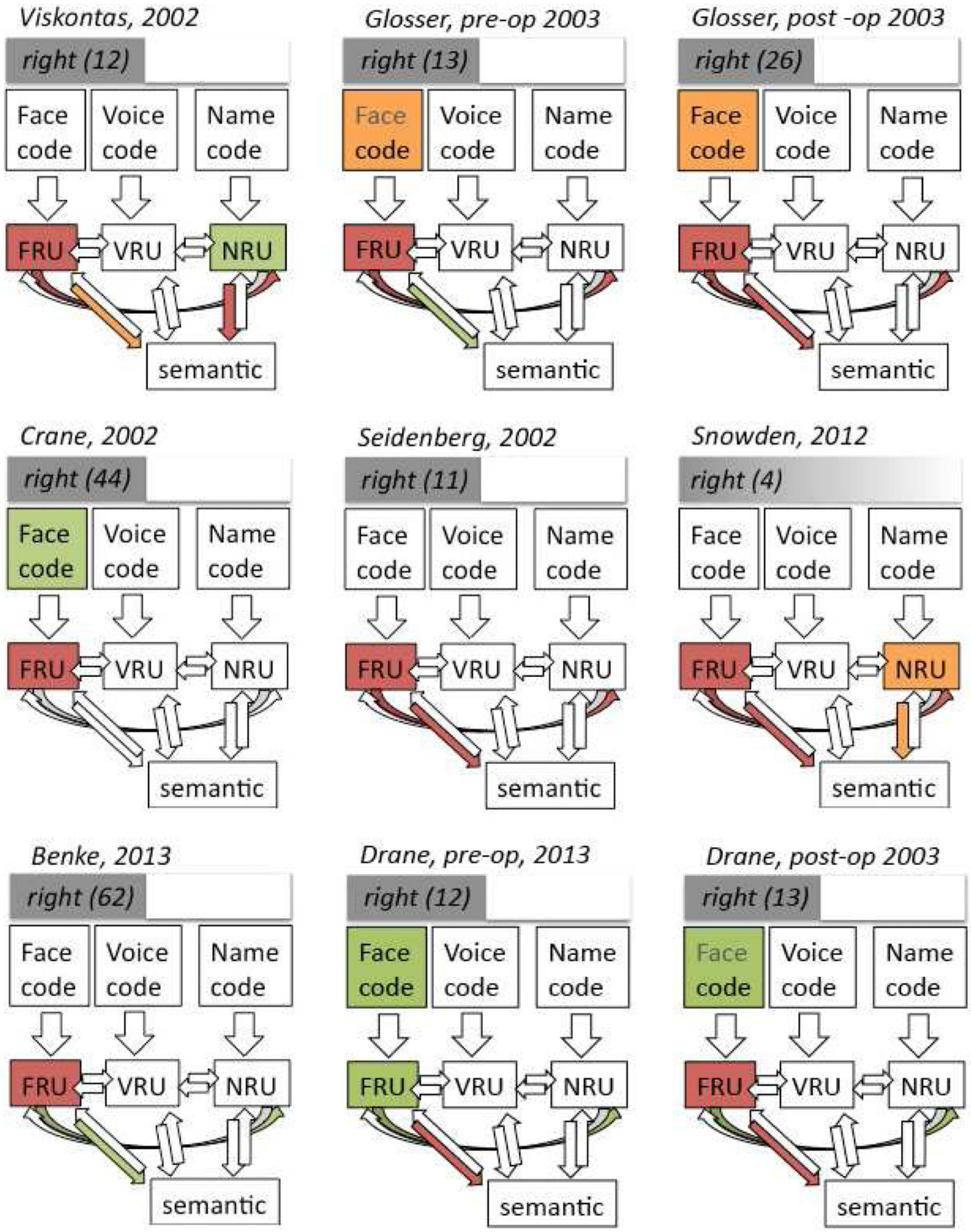

Figure 5.

Cases with impaired familiarity for voice, face or name. Pictorial conventions as in Figure 4. Top row and case 24 in second row are cases with left-dominant lesions, the following show cases with right-dominant lesions, and the last three cases have bilateral lesions without clear dominance.

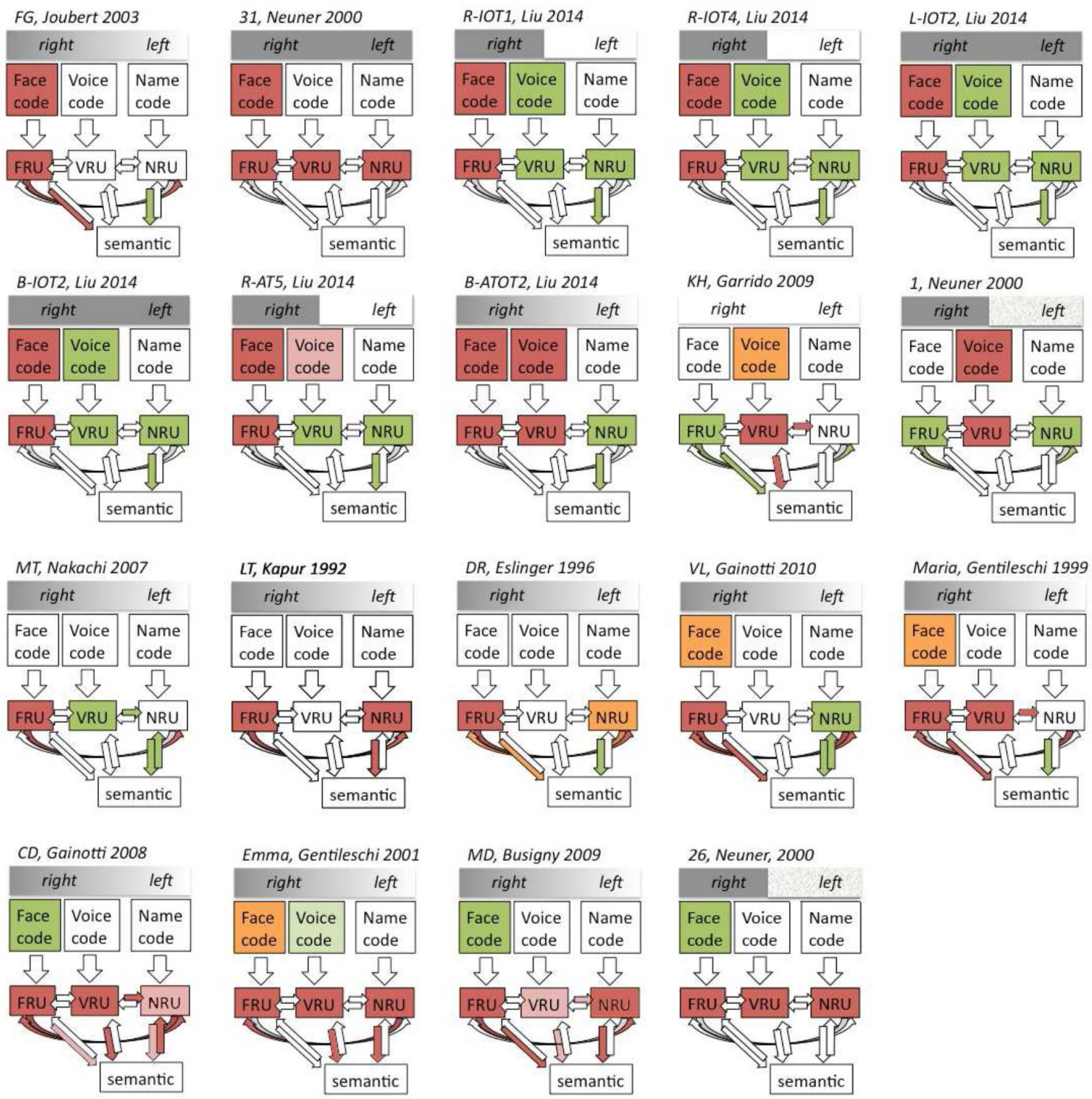

Figure 6.

Cases with impaired linkages. Pictorial conventions as in Figure 4. Top row shows cases of limited value, because assessments of familiarity are either lacking or indicate impairment at the level of recognition units. Middle row shows potentially informative cases with right-dominant lesions, bottom row those with left-dominant lesions.

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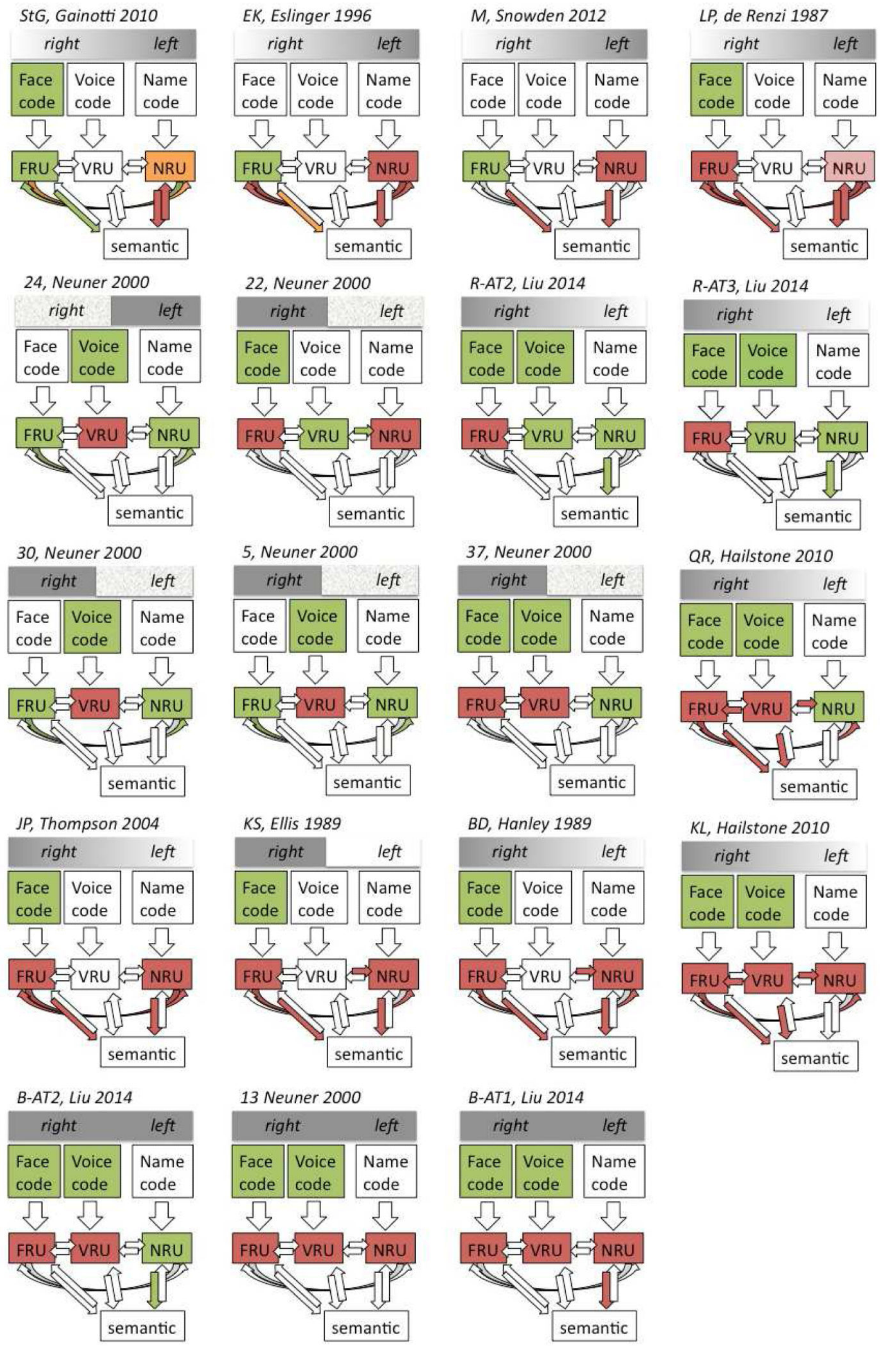

Figure 7.

Group studies, left hemisphere lesions. Pictorial conventions as in Figure 4. The grey zone depicting lesion type for each group also includes reported sample sizes in parentheses.

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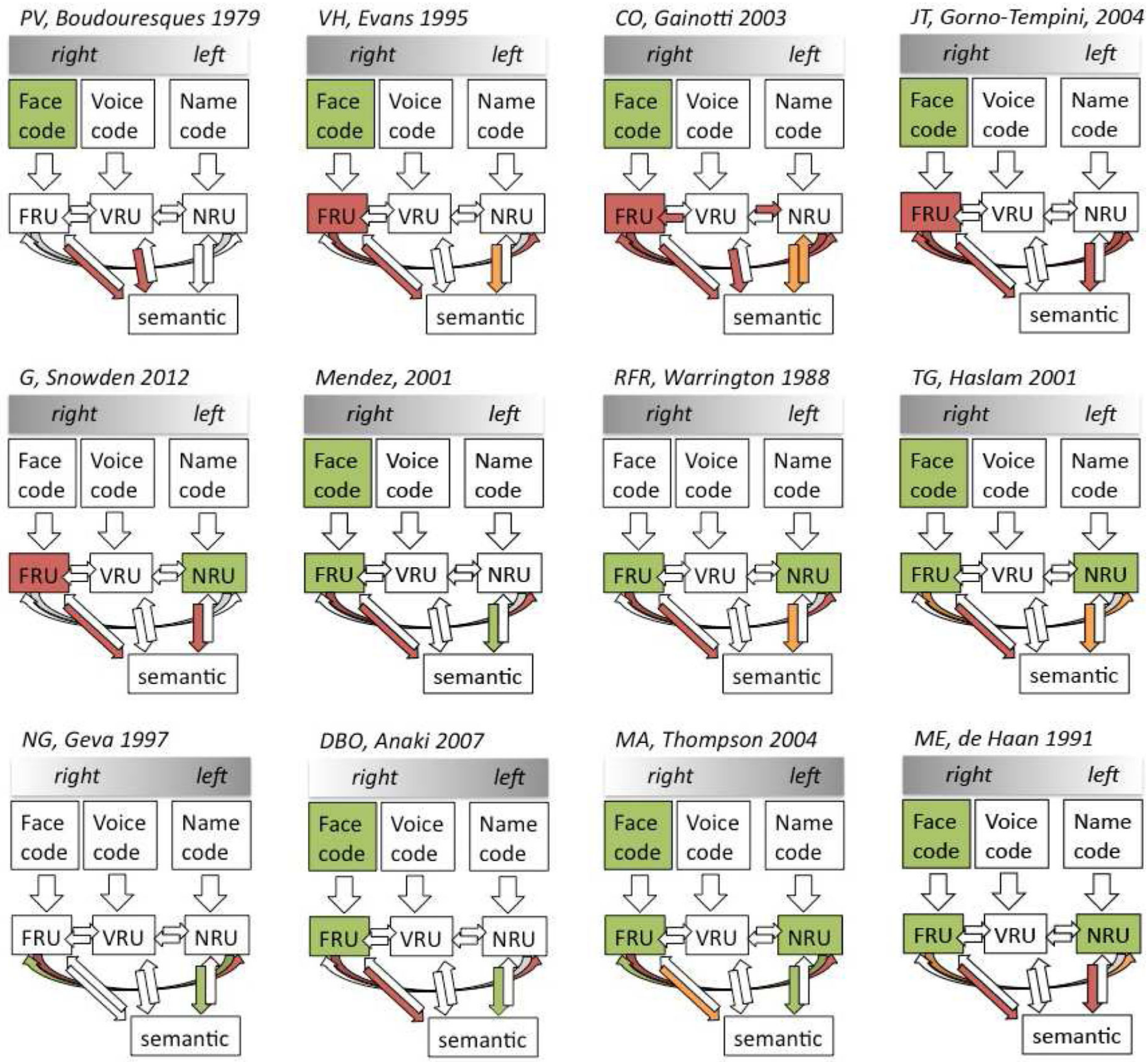

Figure 8.

Group studies, right hemisphere lesions. Pictorial conventions as in Figure 8. The grey zone depicting lesion type for each group also includes reported sample sizes in parentheses.

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Table 1

Measures used in to examine perceptual encoding and familiarity.

				faces			*voices*			*names*
	case	**side**	**etiology**	**perceptual coding**	**familiarity: anonymous**	**familiarity: known**	**perceptual coding**	**familiarity: anonymous**	**familiarity: known**	**familiarity**
Anaki 07	DBO	Lr	infarct	BFRT	WRMT; O/N	fame				
Boudouresques 79	PV	R	encephalitis	MtoS						
Busigny 09	MD	Rl	atrophy	BFRT; config; invert; composite; MtoS	WMS; WRMT	fame; person			person	fame
de Haan 91	ME	B	vasculitis	S/D; BFRT		fame rating; fame				fame rating; fame
de Renzi 87	LP	Lr	encephalitis	BFRT(s); MtoS		fame; fame (MC)				fame
Ellis 89	KS	R	lobectomy	BFRT	WRMT	fame rating				fame rating; fame
Eslinger 96	DR	Rl	encephalitis		WRMT	fame (MC); rating				fame stem; fame (MC); rating
Eslinger 96	EK	Lr	encephalitis		WRMT	fame (MC); rating				fame stem; fame (MC); rating
Evans 95	VH	Rl	atrophy	BFRT; age; gender; gaze	WRMT	fame				
Gainotti 03	CO	Rl	atrophy	BFRT(s); age		fame (MC)				
Gainotti 08	CD	Rl	atrophy	BFRT(s); age		fame; fame (MC)			fame	fame
Garrido 09	KH		developmental		CFMT		S/D	O/N	fame	
Gainotti 10	VL	Rl	atrophy	BFRT(s); age		fame; fame (MC)				fame
Gainotti 10	StG	Lr	atrophy	BFRT(s); age		fame; fame (MC)				fame
Gentileschi 99	Maria	Rl	atrophy	BFRT(s); age		fame (MC); person			person	
Gentileschi 01	Emma	Rl	atrophy	BFRT(s); age		fame; person; fame (MC)	age; gender		person	fame
Geva 97	NG	Lr	encephalitis							
Gorno-Tempini 04	JT	Rl	atrophy	BFRT	WMS	fame (MC)				
Hailstone 10	KL	Rl	atrophy	BFRT		fame; fame	size; gender; S/D		fame	fame
Hailstone 10	QR	Rl	atrophy	BFRT		fame; fame	size; gender; S/D		fame	fame
Hanley 89	BD	Rl	encephalitis	BFRT; express	WRMT	fame rating; fame (MC)				fame rating; fame (MC); fame (MC)
Haslam 01	TG	Rl	encephalitis	BFRT		fame/person				fame/person

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				faces			voices			names
	case	side	etiology	perceptual coding	familiarity: anonymous	familiarity: known	perceptual coding	familiarity: anonymous	familiarity: known	familiarity
Joubert 03	FG	Rl	atrophy	BFRT; age; gender; config	WMS	fame				
Kapur 92	LT	Rl	trauma		WRMT					fame
Liu 14	B-AT1	B	encephalitis	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	B-AT2	B	trauma	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	B-ATOT2	Rl	encephalitis	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	B-IOT2	B	hemorrhage	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	L-IOT2	B	resection, epilepsy	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	R-AT2	R	encephalitis	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	R-AT3	R	encephalitis	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	R-AT5	R	tumor resection	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	R-IOT1	R	hemorrhage	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
Liu 14	R-IOT4	R	infarct	BFRT; config	WRMT; CFMT	fame	MtoS	MtoS		fame
McCarthy 92	RFR	Rl	encephalitis		WRMT	fame				fame; pers
Mendez 01	Case	Rl	atrophy	BFRT		fame				
Nakachi 07	MT	Rl	atrophy		O/N	fame; person			person	
Neuner 00	1	R	not stated			fame	S/D		fame	fame
Neuner 00	5	R	not stated			fame	S/D		fame	fame
Neuner 00	13	B	not stated	BFRT		fame	S/D		fame	fame
Neuner 00	22	R	not stated	BFRT		fame			fame	fame
Neuner 00	24	L	not stated			fame	S/D		fame	fame
Neuner 00	26	R	not stated	BFRT		fame			fame	fame
Neuner 00	30	R	not stated			fame	S/D		fame	fame
Neuner 00	31	B	not stated	BFRT		fame			fame	fame
Neuner 00	37	R	not stated	BFRT		fame	S/D		fame	fame
Snowden 12	G	Rl	atrophy			fame				fame
Snowden 12	M	Lr	atrophy			fame				fame
Thompson 04	JP	Rl	atrophy	BFRT	WRMT	fame				fame
Thompson 04	MA	Lr	atrophy	BFRT	WRMT	fame				fame
Warrington 88	RFR	Rl	encephalitis			fame				fame name completion

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Article is indicated by first author and year. Lesion side is denoted by single letters for unilateral cases, two letters for side-dominant cases, and B for bilateral cases. Abbreviations for measures used are as follows: BFRT - Bention face recognition test (s for short form), age - age discrimination test, gender - gender discrimination test, config - configureation, invert - upright/inverted comparison, composite - face composite task, WMS - Wschsler Memory Scale-III-Faces, WRMT - Warrington recognition memory test, CFMT - Cambridge face memory test, O/N - old/new task, fame - famous faces/voices/names, person - personally familiar faces/voices/names, rating - rating of familiarity, MtoS - match to sample, S/D - same/different task, fame stem - name completion task. MC refers to multiple choice versions of famous or personally familiar face/voice/name tasks, size - indicate physical size of the speaker based on voice, express - emotional expression task, name completion - provide surname when given first name and initial of surname.