THE COGNITIVE APPROACH TO FAMILIAR FACE PROCESSING IN HUMAN SUBJECTS

Serge BREDART *
(University of Liège)

and

Raymond BRUYER
(University of Louvain)

published in Behavioural Processes, 1994, 33, 212-232

Requests for reprints may be sent to S. Brédart, University of Liège, Department of Psychology (B-32), Boulevard du Rectorat 5, B-4000 Liège 1 (Belgium) or to R. Bruyer, University of Louvain, Cognitive Psychology Unit, Voie du roman pays 20, B-1348 Louvain-la-neuve (Belgium).
(*) S. Brédart is Research Associate of the Belgian National Fund for Scientific Research.

ABSTRACT

This paper reviews Bruce & Young's (1986) influential model of face processing, as well as its more recent implementation in the form of an interactive activation network. The multi-componential structure of the model is explained. How this structure can account for empirical effects such as repetition priming, semantic priming or face naming difficulties is briefly discussed. Then, it is shown how the model can be applied to the analysis of a typical neuropsychological impairment of face processing: prosopagnosia. Finally, the intriguing phenomenon of covert face recognition in prosopagnosic patients is briefly reviewed.

Key words: face recognition, interactive activation network, person identification, prosopagnosia.

Introduction

Over the past three decades, the number of studies dealing with face recognition in experimental and cognitive psychology has increased impressively. Such growing interest in this field is probably the result of the psychosocial importance of face processing in everyday-life, since the face is the main source of information for person identification, for communication of emotions, and for verbal (oral) communication. Furthermore, the current increase of studies in the field was probably triggered by two recent phenomena: the publication of cognitive models of face recognition in the eighties, and the progressive emergence of an interdisciplinary approach to this complex process.

Face recognition is fast and automatic but it is certainly not a single operation. Rather, it is the end-product of many underlying subprocesses operating on many different representations. Devising models for these processes (or computations) and representations is the main purpose of the cognitive approach to face recognition or, more broadly, to person identification. From the cognitive point of view, the principal relevant data are collected from groups of young normal adults (students) submitted to subtle experimental manipulations, and from detailed analyses of single patients suffering of a brain lesion damaging specific components of face processing. Additional data derive from investigations in infants and children as well as in elderly subjects (the developmental perspective), from group studies of brain-injured subjects, from slips occurring in everyday activities of normal subjetcs, from electrophysiological cell recording in animals, from research in artificial intelligence and engineering, from applied psychology (eyewitness testimony) and medicine (orthodontics, facial and plastic surgery).

Some visual and cognitive operations can be performed on any face, whether the seen face is already known (i.e. a familiar face) or not (i.e. an unfamiliar face). For instance, from both types of face, one is able to distinguish between a female and a male person, a young and an elderly person, a sad and a happy expression, etc. It is also possible to derive invariant properties to recognize a given face under several poses, distances, contexts or expressions. However, only familiar faces enable the viewer to access pieces of abstract semantic information associated (i.e., by pure learning) to a given face (for instance the occupation, hobby or nationality of the person seen) as well as to the seen person's name.

Before the eighties, virtually all experiments involved unfamiliar faces and the research was focussed on perceptual processes (e.g., discrimination, same/different comparisons, etc.) and episodic memory. In this way, the authors wanted to avoid any interference from face familiarity on the mechanisms investigated. However, familiar faces per se are of interest: the processing of familiar faces is a major feature of everyday visual operations.

In the present review, we will focus on studies investigating the recognition of familiar faces, that is to say, faces that are already known to the subject before the experiment. The first section summarizes the traditional cognitive viewpoint, as expressed by several models designed during the eighties. The second section presents the (more recent) interactive activation view of familiar face processing. The third section is related to a particular defect of familiar face processing resulting form a brain lesion, prosopagnosia (or face agnosia), and its interpretation by means of the cognitive models described in parts 1 & 2. The fourth and final section will show that overt, explicit responses of prosopagnosic subjects don't tell the entire story, since signs of covert or implicit recognition of faces that are not overtly recognized can be shown in some of these patients. Recent overviews of the field can be found in Alley (1988), Bruce (1988), Bruce & Burton (1992), Bruce, Cowey, Ellis & Perrett (1992), Bruyer (1986, 1989, 1990, 1993, 1994), Johnson & Morton (1991) & Young & Ellis, (1989a); (for a short "history" of these models, Bruyer, 1987).

The classical cognitive conception of person identification from faces.

Initial efforts to describe subcomponents and to sketch the cognitive architecture of face processing were made by Bruce (1979) and by Hay & Young (1982). Later, some authors attempted to integrate what was known about cerebral functional asymmetry (Ellis, 1983; Rhodes, 1985). Finally, this period culminated with cognitive architectures proposed by Ellis (1986) and by Bruce & Young (1986; Young & Ellis, 1989b, for an updated version). Clearly, these models were inspired directly by the logogen model of word recognition devised previously by Morton (1969; Morton & Patterson, 1980) and its application to visual recognition of objects (i.e. the pictogen model: Ratcliff & Newcombe, 1982; Warren & Morton, 1982). The Bruce & Young (1986) model was much more frequently cited than the one by Ellis (1986). In fact, the two models are very similar, differing only on two points. Firstly, unlike Bruce & Young, Ellis suggests an initial structural encoding stage by which the processing system makes a facial decision, i.e., categorizes the object seen as "a human face" as opposed to non-facial patterns. Secondly, visual analyses of age, gender, race, etc. of the person seen are considered as mandatory for face recognition by Ellis whereas, for Bruce & Young, they are not necessary for face recognition (but Bruce, Ellis, Gibling & Young, 1987, reported empirical evidence favouring the second thesis).

The following presentation will be limited to the Bruce & Young model (see Figure 1) since this model may be considered as the main reference point in the field.

- -

INSERT FIGURE 1 ABOUT HERE

- -

The core-concept (first introduced by Hay & Young,1982) of the model is the register of **face recognition units** . It is a long-term store of representations of the faces already known by the perceiver, one recognition unit corresponding to each known face. In the logogen-like model of Hay & Young (1982), a recognition unit was conceived of as firing in an all-or-none, threshold manner when the current input bears sufficient resemblance to the stored representation, and this firing corresponds to the recognition of the face. According to the model developed by Bruce & Young, however, a unit fires proportionally to the ressemblance between the input and the stored representation, and the decision process of recognition is made by the cognitive system (which may require additional visual analyses before making a decision). Nevertheless the face recognition unit is still assumed to be the key component for familiarity decisions.

By analogy with neural properties and in agreement with other cognitive models of recognition (e.g. word recognition), once a recognition unit has been activated, the return to the resting state is not instantaneous. Thus, its excitability is higher than that of other face recognition units for some time. This can explain repetition (or identity) priming (Bruce & Valentine, 1985; Ellis, Young, Flude & Hay, 1987; Brunas, Young & Ellis, 1990). "Priming" means the facilitation of the recognition of a given face (the target) by the previous exposure to a related stimulus (the prime); "**repetition priming**" means the facilitation of the recognition of a given face by the previous exposure to the stimulus. This can be explained by the temporary excitation of the face recognition unit which is shared by the two stimuli. It should be noted that repetition priming is long lasting (several minutes or hours), but it is a strictly within-domain effect: this kind of priming is induced only if faces of the same individual are used as prime and target (for instance, the written name of a famous person does not prime the recognition of this person's face when the interval between the prime and the target exceeds a few seconds). Of course, the prime may be another view of the target face (for instance the same face displaying another expression or another pose), since true face recognition should not be reduced to "picture" or "stimulus" recognition and supposes (see below) the extraction of structural invariants specific to a given face irrespective of its expression. Nevertheless, the magnitude of the priming is proportional to the pictorial similarity between the prime and the target.

The nature and format of these recognition units are conceived of as analogical representations (instead of series of propositional representations) which emphasize characteristic features of the face (a caricatured representation: see, for instance, Rhodes, Brennan &

Carey, 1987). In this way, the set of facial representations can be conceptualized as a multidimensional space where the central point would correspond to a facial prototype and in which each face is a specific point (Valentine, 1991). This approach can explain a lot of empirical findings about episodic recognition of faces -such as the distinctiveness effect or the other-race effect- since each face is characterized by its distance from other faces (for instance, assuming that the prototype is in some way the "mean value" of all previously encountered faces, the density of points decreases with increasing distance from the prototype, so that distinctive [that is to say, non-prototypical or unusual] faces are better recognized because there is no other face in their close proximity: known as the **distinctiveness effect.** However, other-race faces, albeit far from the prototype, form a cluster close to each other, so that faces of another race are difficult to distinguish: known as the **other-race effect**).

The activation of the recognition unit register will then give access to semantic pieces of information describing the identity of the seen person, the **Person Identity Nodes** . These pieces of information are related to knowledge about the person seen, such as its occupation, nationality, hobbies, etc. The authors remain rather vague as to whether the activation of this node gives access to semantic pieces of information (stored elsewhere) or if the node is itself a register of semantic information (called the "Identity Specific Semantic Codes"). It should be noted that this "post recognition unit" stage of the processing can be activated by other entries than faces (e.g., the silhouette, name, voice, etc., of the person seen), each having its own perceptual device and store of recognition units (Young, Hay & Ellis, 1985a). This "cross-modal" nature of the input of the identity nodes can explain another kind of priming, **semantic priming**. By this procedure, it is shown that the identification of a famous face can be facilitated by the previous exposure to the name or the face of a closely related person (for instance, the name "Laurel" facilitates the recognition of the face of Hardy: Bruce, 1986; Bruce & Valentine, 1986; Young, McWeeny, Hay & Ellis, 1986a; Young, McWeeny, Ellis & Hay, 1986b, Young, Hellawell & De Haan, 1988). Unlike repetition priming, semantic priming is short lived and cross modal (see also Rhodes & Tremewan, 1993).

Finally, if and only if (Young et al., 1985a; Schweich, Van der Linden, Brédart, Bruyer, Nelles & Schils, 1992; Hay, Young & Ellis, 1991) a given person identity node has been activated, the system can access the **Name Codes** and engage processes of name retrieval and production (and it could be that the address of a person have a similar cognitive status: see Bruyer & Scailquin, 1994). Thus, in this model names are stored in a separate and final component. This would explain the empirical fact that a person's name is a piece of information which is particularly difficult to retrieve (for extensive review of data, see Valentine, Brennen & Brédart, 1994).

The proposal that face recognition units, person identity nodes and name codes are activated in a sequential manner is well supported by empirical results arising from different methodological paradigms: mental chronometry (Bruyer, Galvez & Prairal, 1993; Sergent, 1986; Young et al., 1986a & 1986b; Young, Ellis & Flude, 1988; Johnston & Bruce, 1990), learning situations (Cohen & Faulkner, 1986; Cohen, 1990; McWeeny, Young, Hay & Ellis, 1987; Bruyer, Van der Linden, Lodewijck, Nelles, Schils, Scweich & Brédart, 1992), analyses of failures of face processing in everyday life (Young et al., 1985; Schweich et al., 1992) or in the laboratory (Hanley & Cowell, 1988; Brennen, Baguley, Bright & Bruce, 1990; Hay et al., 1991) and single-case studies in neuropsychology (McKenna & Warrington, 1980; Flude, Ellis & Kay, 1989; Lucchelli & De Renzi, 1992; Semenza & Zettin, 1988 & 1989; Shallice & Karsounis, 1993).

It remains to make a comment about **the input to the register of face recognition units**. This input is the result of a series of visual and perceptual operations made on the current stimulus, whether this stimulus is known or not. The stimulus is analyzed (structural encoding) in order to derive an invariant representation of the face, that is to say, a representation independent of the current pose, expression, distance, etc. of the seen face (this process allows the viewer to detect common featural properties of, say, two different views of the same face [as illustrated by Fig.1]). This invariant representation will then be matched to a recognition unit if the face is already known or resembles a known one. Simultaneously, there are visual operations that can be accomplished on known and unknown faces. These operations are not mandatory for the recognition process and are made in parallel to it: lipreading behaviour (facial speech analysis), the analysis of facial expression, and the extraction of semantic properties from surface facial features (the "visually-derived semantic codes", which extract the apparent age, gender, race, etc. of the face seen). Since the publication of the Bruce & Young model, new data have suggested that recognition of the gaze direction of the face seen could be added to this list of visually-derived semantic codes: Perrett, Mistlin, Chitty, Harries, Newcombe & De Haan, 1988; Campbell, Heywood, Cowey, Regard & Landis, 1990).

It is worth noting that the structural components of faces are not really known. First, the "features" in the usual sense (i.e., the mouth, eyes, nose, hair, etc.) are probably important but not sufficient. Indeed, it is well established that configural, second-order relationships between these features are highly important in face recognition (for instance, Sergent, 1984; Diamond & Carey, 1986; Rhodes, Brake & Atkinson, 1993) and that inversion disrupts specifically the processing of this configural information (Rhodes et al., 1993). Second, even "features" differ in saliency for face recognition (Shepherd, Davies & Ellis, 1981 for a review). Moreover, internal or inner features are more important than external or outer features in the processing of familiar faces while internal and external features are equally important in the processing of unfamiliar faces (Ellis, Shepherd & Davies, 1979; Young, Hay, McWeeny, Flude & Ellis, 1985b; De Haan & Hay, 1986; Hosie, Ellis & Haig, 1988).

An interactive activation view of face recognition

More recently, Burton, Bruce & Johnston (1990) designed an interactive activation and competition (IAC) network in order to explore the microstructure of the Bruce & Young model. We will show that Burton & al. (1990) framework offered an interesting account of mechanisms underlying semantic priming and repetition priming effects in face recognition. This architecture was also developed to provide a new insight for other phenomena like covert face recognition, face naming difficulties or distinctiveness effects.

IAC models comprise a number of units organized into pools or clusters. All the units within the same pool are interconnected with inhibitory links, whereas excitatory links connect associated units from different pools. All links are generally bidirectional. In this kind of model, input units receive the input from an experimenter. Time may be modelled in terms of a number of processing cycles. After each cycle the activation of units is updated. Activation is passed along excitatory links into the different pools so that the level of activation of associated units increases. There is also a global decay function that forces units towards a resting activation. Units tend to stabilize when the effect of input activation is balanced by the effect of decay. Extensive and comprehensive reviews of the properties of IAC networks may be found in Rumelhart, McClelland, & the PDP Research Group (1986) or in Bechtel & Abrahamsen (1991).

Burton et al.'s (1990) network contained three kinds of units: Face Recognition Units (FRUs), Person Identity Nodes (PINs) and Semantic Information Units (SIUs). As in the Bruce & Young (1986) model, FRUs are assumed to hold stored structural descriptions of faces; there is one FRU for each familiar face. Bruce & Young did not explicitly state whether identity-specific semantic information is stored in the PINs or accessed via the PINs, however many authors interpreted that the model prescribed that the PINs contained biographical information about people (e.g. Flude et al., 1989; Cohen, 1990; Brédart & Valentine, 1992). This ambiguity is avoided in Burton et al.'s (1990) model: PINs are just cross-domain and modality-free gateways to biographical information. Information describing the identity of individuals is stored at the SIUs level (see figure 2). It is important to stress that, in this model, familiarity decision are assumed to be taken at the PINs level. We noted earlier that the Bruce & Young model might imply separate decision mechanisms for the different input domain (e.g. face, voice, body, name). By contrast, Burton et al. considered that it would be more parsimonious to conceive of a pool of units responsible for ***person*** familiarity judgements.

INSERT FIGURE 2 ABOUT HERE

- -

Basically, in Burton et al.'s computer simulations, the experimenter sets an input to a FRU whose activation consequently increases. This FRU sends an output to its corresponding PIN which in turn sends an output to its connected SIUs. Person recognition is assumed to occur when a target PIN reaches an arbitrarily set threshold. Hoes does this architecture accounts for the **semantic priming** phenomenon? Figure 3 show the activation of two PINs after an input has been set for a single FRU. In this example, the "Prince Charles" FRU receives the input from the experimenter and becomes active, the activation of the "Prince Charles" PIN consequently rises. Units holding descriptive properties defining Prince Charles identity (e.g. British, Royal) receive input from the "Prince Charles" PIN and become active. These units then send activation to all the connected PINs, i.e. feedback activation to the "Prince Charles" PIN but also activation to the PINs of other individuals sharing these properties. For instance, the activation of the "Princess Diana" PIN also rises. As shown in figure 3, the "Prince Charles" PIN, which directly receives activation from an input unit, quickly rises above the threshold value. The Princess Diana" PIN also rises but stabilizes below the threshold value. In this kind of simulation, the inter-stimulus interval of the semantic priming procedure may be modelled by running the system with no external input during a number of cycles (80 cycles in Burton et al., 1990). At the end of the inter-stimulus interval, no PIN reaches the threshold anymore, however the "Princess Diana" PIN remains above resting activation. Consequently, when, after this interval, an input is sent to the "Princess Diana" FRU, the "Princess Diana" PIN reaches threshold faster than "Prince Charles"PIN did in the first phase of the simulation. That is how Burton et al. modelled semantic priming in their network.

INSERT FIGURE 3 ABOUT HERE

We mentioned earlier that semantic priming was a short-lived effect. How does the model explain this time course of semantic priming? Two factors, which have been widely confused in the literature on face processing, may play a role in the decay of semantic priming: time and the number of unrelated intervening stimuli. In Burton et al.'s network, PINs decay slowly when no input is sent to the system, but setting an input to the FRU of a person (e.g. Michael Jackson) that is semantically unrelated to the target PIN (e.g. Prince Charles) elicits a quick decay of the latter's PIN activity. Thus, in this model, the presentation of an intervening stimulus is the major factor explaining the decay of semantic priming; time plays only a minor role.

In the given example, the prime and the target belonged to the same stimulus domain (i.e. faces). Burton, Young, Bruce, Johnston & Ellis (1991) also presented a simulation of semantic priming from names to names. However, it must be emphazised that the model may also account for cross-domain semantic priming. Burton et al., (1991) successfully applied the framework to a semantic priming situation that involved faces as primes and names as targets. In a parsimonious way, the model gives the same explanation for cross-domain semantic priming as for within-domain semantic priming.

The way Burton et al. (1990) modelled **repetition priming** is very different. A successful simulation of repetition priming effects was obtained by strengthening links between the FRU and the PIN. For instance, when the "Prince Charles" FRU reached the threshold value, the strength of the connection between the "Prince Charles" FRU and the "Prince Charles" PIN was increased. Of course, the result of this manipulation was that when the "Prince Charles" FRU is activated again, the "Prince Charles" PIN reached threshold more quickly than before. This manipulation simulated two important characteristics of repetition priming: repetition priming does not apply across domains and it is a long lasting phenomenon.

Bruce & Young (1986) explained why names are more difficult to retrieve than descriptive properties about people, by postulating that names are stored in a final component (i.e. the Names Codes) that may be accessed only via identity-specific semantics. A number of researchers came to find this account for difficulties of name retrieval to be unsatisfactory. For instance, Johnston & Bruce (1990) stated "In the Bruce & Young model at present, name and semantic information is stored in different sites, but this only reframes the question of difference without explaining it" (p. 63). Burton & Bruce (1992, 1993) extended Burton et al.'s network in order to provide an account of the relative difficulty of **name retrieval** which does not necessitate a separate stage of access to name codes in the face recognition system. They included units representing names in the pool of SIUs. Thus, in the Burton & Bruce model, names are represented alongside semantic information that defines the identity of individuals. Using such an architecture, Burton & Bruce obtained results consistent with the empirical fact that names are harder to retrieve than pieces of biographical information such as occupation or nationality. In this framework, the property that makes names harder to retrieve is ***uniqueness***. Names represent an unique or little shared characteristic (finding two individuals sharing exactly the same name is far less common than finding individuals sharing a property like an occupation, a nationality or a marital status). This has led Burton & Bruce to predict that a unique descriptive property known about an individual should be as difficult to retrieve as his or her name. This prediction has not yet been tested empirically. However, there is a prediction from Burton & Bruce's model that does not fit the empirical data. This model predicts that the more properties that are known about a person, the more difficult that person's name should be to retrieve. This prediction is hardly compatible with the fact that the more familiar a person is, the less likely this person's face elicits naming failures (Brédart, 1993). Moreover the prediction is inconsistent with the finding that latencies to name famous faces about whom few biographical details were known was longer than latencies to name equally famous faces about whom many pieces of information were known (Brédart & Valentine, 1993). Thus, the IAC model developed by Burton and collaborators was less successful in modelling name retrieval than in modelling the other above-mentioned aspects of familiar face processing (see also Stanhope & Cohen, 1993). Of course this does not mean that there no possible way of modelling face naming with an interactive activation network.

Prosopagnosia a neurological selective deficit of familiar face identification

Nature is capricious and, in some (rare) cases, brain damage specifically impairs the recognition of familiar faces. This face agnosia or prosopagnosia (from the Greek "prosopon"= face: Bodamer, 1947/1990) is said to be specific at several levels. First, it is an agnosia, i.e., a recognition deficit that cannot be attributed to sensory disturbances or to general cognitive, memory, intellectual or linguistic deficiencies. Second, the trouble is limited to the visual channel. Third, the defect concerns faces, not other visual mono-oriented complex stimuli (there is a debate about this point [e.g., Damasio, Damasio & Van Hoesen, 1982, suggested that the defect would concern every classes of "ambiguous" stimuli, i.e. categories whose exemplars are structurally very similar to each other], but see McNeil & Warrington, 1993). Fourth, it is the recognition stage of the processing that is defective, that is to say, the sight of previously known faces no longer triggers any feeling of familiarity: all faces appear to be new or unknown. Thus, structural encoding, processing of facial expressions, analysis of gender, age, lipreading, etc. are generally relatively spared; in the same way, persons are recognized by their voice, clothes, silhouette, etc. Fifth and finally, the deficit concerns familiar faces only, i.e., faces that were well known before the brain lesion and, usually, faces frequently met after the onset of the disease.

This phenomenological description of face agnosia does not imply that prosopagnosia is the sole deficit of the patient. In fact, associated deficits are often found (see Farah, 1990, 1991, for an attempt to interpret the various patterns of co-occurrence of prosopagnosia, visual agnosia for objects, and alexia). Prosopagnosia is not the sole deficit of face recognition (for instance, some psychiatric conditions as in Capgras delusion and Frégoli delusion can lead to apparently similar behavioural patterns: see Ellis & Young, 1990; Young, Ellis, Szulecka & De Pauw, 1990), and is not the sole neurological deficit of person processing (for instance, specific anomia [word finding difficulties] for persons' names have been reported in non-prosopagnosic patients: McKenna & Warrington, 1980; Lucchelli & De Renzi, 1992; Carney & Temple, 1993; Shallice & Kartsounis, 1993).

Over one century, about 150 cases of prosopagnosia have been reported in the literature. Autopsy findings show that the lesions generally involve the occipitotemporal regions of both hemispheres (Damasio et al., 1982; Meadows, 1974), even if the right hemisphere seems to be critical in this respect (De Renzi, 1986a; Landis, Cummings, Christen, Bogen & Imhof, 1986; Landis, Regard, Bliestle & Leihnes, 1988; see Michel, Poncet & Signoret,1989 for a review). However, whatever the issue of the debates about the neuropathological mechanisms underlying prosopagnosia, it is worth noting that this cognitive deficit can be interpreted within its own, "cognitive" domain. For instance, Damasio et al. (1982) suggested a contextualist interpretation, that is to say, prosopagnosia could manifest a defective recall of the context associated with a given face. Tiberghien & Clerc (1986) have also suggested that their prosopagnosic patient was impaired in deciding whether the feeling of familiarity resulted from the face seen or from the context in which it was seen (see also Schweich & Bruyer, 1992). More generally, the detailed analysis of isolated cases did contribute to the design of the cognitive architecture underlying the normal face processing which, in turn, guided the way by which prosopagnosics are currently examined. This cross-fertilization is illustrated in the remainder of the present section.

Prosopagnosics do not suffer from a person agnosia, i.e., they are generally able to identify a person by other cues than his or her face (e.g., the voice, name, gait, etc.). This supports the general architecture shown in figure1 according to which several inputs converge to the Person Identity Node, the firing of it indicating the recognition of the person. Moreover, the multi-componential structure of face processing (as shown in figure 1) is well supported by detailed studies of cases of prosopagnosia. For instance, the patient investigated by Bruyer, Laterre, Seron, Feyereisen, Strypstein, Pierrard & Rectem (1983) was clearly prosopagnosic, but performed normally in several tasks designed to test the processing of facial expressions and the structural encoding of faces, including gender categorization and facial decisions. Similarly, Tranel, Damasio & Damasio, (1988) reported a preserved processing of facial expressions, gender and age of faces in three out of the four prosopagnosics investigated. Malone, Morris, Kay & Levin (1982) described two prosopagnosic patients with contrasting histories since, in one case, the prosopagnosia disappeared but the patient remained impaired in the visual analysis of unfamiliar faces, while, in the other subject, the prosopagnosia persisted but the processing of unfamiliar faces improved. Campbell, Landis & Regard (1986) offered a nice example of double dissociation between the processing of identity from faces, and lipreading, since a prosopagnosic patient was impaired in processing facial expressions but lipread efficiently while a second, non-prosopagnosic subject was impaired in lipreading. De Renzi, Bonacini & Faglioni (1989) submitted four prosopagnosics to a test for assessing the apparent age of faces: three of them were deeply impaired in this task while the fourth displayed scores in the range of his control group of posterior right-damaged subjects.

The functional architecture described above has also proved to be a heuristic by triggering studies precisely planned to test it, particularly in extending the search toward non-prosopagnosic patients. For instance, the model predicts dissociations between the recognition of facial expressions, the recognition of familiar faces, and the structural encoding of unfamiliar faces. Parry, Young, Saul & Moss (1991) designed tests for these three subcomponents where the same material was used and task demands equated, and enrolled an unselected group of 15 brain-injured subjects. In agreement with the predictions, they detected one subject who was impaired in every tests, three patients deficient for two of the three tests (note that, in each case, the recognition of facial expressions was preserved) and, above all, four subjects with a deficit limited to only one task. Interestingly enough, one subject was only deficient in recognizing facial expressions, another subject was only deficient in processing the identity of unfamiliar faces, and the remaining two patients were only deficient in recognizing familiar faces. Moreover, the two prosopagnosics reported by Campbell et al. (1990) performed adequately in tasks testing the structural encoding of faces, the visually-derived semantic codes and the processing of facial expressions. However, an interesting dissociation emerged, since only one of them was unable to detect frontal eye gaze in the faces seen. Similarly, the model predicts that one should find a patient deficient at accessiing Identity-Specific Semantic Codes but unimpaired on tasks tapping visual analysis of faces, access to the Face Recognition Units and access to the Name Recognition Units. Accordingly, De Haan, Young & Newcombe (1991) detected an amnesic patient displaying precisely the predicted pattern.

Also, the model predicts that one could find a brain-injured patient with a selective deficit in naming familiar faces. And indeed, Flude, Ellis & Kay (1989) investigated an aphasic subject (aphasia is a language disturbance resulting from brain damage) who was unable to name familiar faces but performed normally in tasks testing the structural encoding of faces, the access to Face Recognition Units and Name Recognition Units, and the retrieval of Identity-Specific Semantic Information. Finally, the general architecture of the model suggests that one must be able to identify a patient who is not prosopagnosic per se but suffers from a person agnosia. Accordingly, Hanley, Young & Pearson (1989) reported a patient who was unable to recognize familiar people by their face, their name, and their voice.

However, the functional model described above includes some potentially weak points. For instance, it predicts a possible dissociation between the visually-derived semantic codes and the recognition of facial identity, but a patient who is not prosopagnosic and able to derive a normal structural encoding of faces in the context of an impaired processing of age or gender of faces is still to be reported. Furthermore, Davidoff & Landis (1990), from an in-depth analysis of four prosopagnosic subjects, cast doubts on the face specificity of the deficit and on the sparing of unfamiliar faces processing, of the facial decision stage, and of the processing of facial expressions in prosopagnosia.

The multi-componential architecture of the functional model as well as the diversity of prosopagnosic patients reported in the literature led authors to suggest several forms of prosopagnosia, a "syndrome" that should be fractionated. Thus, De Renzi, Faglioni, Grossi & Nichelli (1991; see also De Renzi, 1986b and De Renzi et al., 1989) submitted three prosopagnosic subjects to a battery of tests tapping several loci of the functional architecture and concluded that one should distinguish between an apperceptive and an associative form of prosopagnosia, using a distinction previously applied by Lissauer (1890/1988) to visual object agnosias (broadly speaking, in apperceptive agnosia, patients are unable to recognize objects due to deficits of high-level perceptual processes, while in associative agnosia, patients do not recognize objects because the perceptual representation which is derived is meaningless). An analogous conceptual approach was made by Schweich & Bruyer (1993) with a group of ten prosopagnosic subjects. Similarly, Damasio, Tranel & Damasio (1990) proposed three kinds of face agnosia, namely, amnesic associative prosopagnosia, pure face agnosia, and several forms of partial face agnosia. Finally, McNeil & Warrington (1991) proposed a distinction between prosopagnosia resulting from a disconnection of the register of Face Recognition Units (from other stores of representations), and prosopagnosia resulting from damage to the recognition units themselves.

This last suggestion was based on observations of covert face recognition in some, but not all, prosopagnosics. This intriguing phenomenon will be reported in the next section of this paper.

Covert recognition of familiar faces in prosopagnosia

Patients with no overt recognition of faces (i.e. patients who show no feeling of familiarity with faces of known individuals and whose ability to sort familiar from unfamiliar faces is random) may show signs of covert recognition (i.e. differential responses to familiar and unfamiliar faces when no explicit recognition is required). This has been demonstrated using different kinds of physiological and behavioural measures (Bruyer, 1991 for a review).

For instance, Bauer (1984) reported different electrodermal responses to correct and incorrect face-name matches in a patient who was unable to recognize the presented faces overtly. Tranel & Damasio (1985, 1988) found that electrodermal responses were greater to familiar faces than to unfamiliar faces in several patients who failed to recognize overtly these familiar faces. Signs of covert recognition via the measurement of brain evoked potentials (P300 amplitude) have also been reported (Renault, Signoret, Debruille, Breton & Bolgert, 1989).

Apart from these peripheral and central physiological indexes, researchers found behavioural evidence for covert recognition. Using an eye-movement recording procedure, Rizzo, Hurtig & Damasio, (1987) described two prosopagnosic patients who showed differential inspection of familiar, but overtly unrecognized, faces and unfamiliar faces: the patients inspected the entire face when unfamiliar faces were presented whereas they focussed more on the internal area of famous faces. In other words, these patients, like normal subjects, showed an effect of familiarity on the pattern of face inspection. De Haan, Young & Newcombe, (1987a) described a patient (PH) who was faster at matching identities of familiar than identities of unfamiliar faces, although no overt recognition of these familiar faces occurred. Moreover, when showed with incomplete stimuli, PH showed that advantage for familiar faces when only internal features of faces were presented but not when only external features were presented. This pattern of results is similar to that found in normal subjects (Young et al., 1985b; Young, Ellis, Flude, McWeeny & Hay, 1986c).

The available data show that some prosopagnosic patients give a differential response to familiar and unfamiliar faces. They suggest both that the stored structural descriptions of familiar faces ("Face Recognition Units" in the models described earlier) are not destroyed in these patients, and that the access to these descriptions is at least partially effective. Other data show that access to biographical information about familiar people may also be covertly accessed by some prosopagnosic patients. The case of the patient PH has been particularly well documented. The patient was presented with an interference task in which a face and a name were simultaneously displayed. The task consisted of categorizing names as being those of politicians or not whereas the presented faces were to be ignored. In this kind of name classification task, normal subjects' reaction times (to politicians') names are longer when these names are displayed with faces of non-politicians than when they are displayed with faces of politicians (Young et al., 1986c). The same pattern of results was obtained with PH (De Haan et al., 1987a & b). Therefore, the sight of an overtly unrecognized face influenced semantic classification of names. Moreover, Young et al. (1988) were able to show semantic priming in PH by using a task that involved faces as primes and names as targets. Thus, the presentation of an overtly unrecognized face influenced PH's reaction times to a semantically related name. Learning procedures have also been used. Subjects learned true and untrue face-name or face-occupation associations (Bruyer et al., 1983; De Haan et al., 1987a; Young & De Haan, 1988; Sergent & Poncet, 1990). In this kind of task, PH's performance was better for the true pairings than for the false, despite of the fact that he was again totally unable to overtly recognize the faces involved in the task. This advantage for true face-occupation pairings was obtained only if information given about the occupation was general (e.g. politician, actor) but not if information was more precise (for instance a sporting category). However, this superiority was obtained even for precise information with another patient (Hanley et al., 1989).

Before briefly reviewing the explanations that have been given to account for covert recognition, it is important to note that covert recognition is not associated with all cases of prosopagnosia. Several authors have described patients who do not show signs of covert recognition, on the basis of physiological indexes (Bauer, 1986; Small, 1988), behavioural indexes (Young & Ellis, 1989c; Newcombe et al., 1989; McNeil & Warrington, 1991), or both (Etcoff et al., 1991).

Young & De Haan (1988) suggested that covert recognition associated with prosopagnosia might be seen as an impairment that involves a loss of awareness of the products of the face recognition system: "Covert recognition effects in prosopagnosia can be considered to reflect the operation of a partially isolated face recognition system (p. 317). In terms of the Bruce & Young (1986) model (see figure 1), covert recognition would reflect damage in the pathways from face recognition units to both the person identity nodes and the cognitive system. The content of FRUs themselves would not be damaged in subjects like PH. This explanation does not directly account for the fact that PH showed covert access to general semantic information in interference and priming tasks, as well as in face-occupation learning tasks. In order to account for this, Young & De Haan were obliged to assume "some form of rudimentary semantic organisation at the recognition unit level", i.e. connections between recognition units that could produce interference and semantic priming effects. Such connections would enable the recognition system to be prepared for whatever is likely to be encountered next. These connections, which were not included in the original Bruce & Young model, have a special status: they do not serve to trigger directly the firing of an associated recognition unit but they would have the effect of lowering decision thresholds. This amendment to the Bruce & Young model was a somewhat ad-hoc change which does not seem very parsimonious.

Burton et al. (1991) proposed another possible account for covert recognition in the terms of Burton et al. (1990) interactive activation model which we described earlier. They proposed that PH's functional impairment lies in an attenuation of connections strengths between the pool of FRUs and the pool of PINs (see figure 2). More precisely, the mechanism is as follows. excitation is passed from a normally active FRU to its associated PIN through an attenuated link. This results in a sub-threshold activation of the PIN (the faces is not overtly recognized). Nevertheless this PIN will pass some activation to its associated SIUs which in turn will pass some activation to their associated PINs. It should be noted that "the only difference between this and the intact system is that the levels of activation will be smaller" (Burton et al., 1991, p. 145). These authors tested their hypothesis by simulating two covert recognition effects that had been previously tested with PH: semantic priming and interference from "unrecognized" faces. Consistent with these authors' predictions, the simulations clearly showed that it is possible to attenuate FRU-PINs links so that semantic priming effects and interference effects occur while the PIN of the prime or the distractor reach only a subthreshold activation.

More recently, Wallace & Farah (1992) disagreed with the notion that the presence of covert recognition is an evidence that the access of the recognition system to other systems underlying awareness is impaired whereas face recognition per se is not impaired. It is important to note that Wallace and Farah's account simply do not resort anymore to the "access to consciousness" concept. For Wallace & Farah, the face recognition system of prosopagnosic patients showing covert recognition is impaired. The occurrence of covert recognition without explicit recognition simply reflects the fact that covert recognition tasks are more sensitive measures of knowledge than overt recognition tasks. Moreover, the fact that some patients show covert recognition while other do not, would simply indicate that the latter patients have more complete damage to their recognition system than the former ones.

Concluding remarks

In the present paper, we have presented Bruce & Young's (1986) model of familiar face recognition as well as its more recent implementation in the form of an interactive activation and competition network. This general framework proved to be particularly heuristic. It has guided, and still guides, a considerable amount of studies in the field. Although the model was designed mainly to understand face recognition, it provides a general framework for the study of person recognition from other input domains than faces. For instance, Valentine, Brédart, Lawson & Ward (1991) proposed a model of person recognition from written or spoken names which was directly inspired by the Bruce & Young model. Similarly to the developments in the modelling of face recognition, an interactive activation version of Valentine' & al.'s model was proposed a little later (Burton & Bruce, 1993). As compared to the study of recognition of faces and names, the study of person recognition from their voice or body has so far received little attention and should be developed in the coming years.

REFERENCES

Alley, T.R. (Editor), 1988. Social and Applied Aspects of Perceiving Faces. Lawrence Erlbaum Associates, Hillsdale, NJ, 285 pp.

Bauer, R.M., 1984. Automatic recognition of names and faces in prosopagnosia: A neuropsychological application of the guilty knowledge test. Neuropsychologia, 26: 105-117.

Bauer, R.M., 1986. The cognitive psychophysiology of prosopagnosia. In: H.D. Ellis, M.A. Jeeves, F. Newcombe and A.W. Young (Editors), Aspects of Face Processing, Nijhoff, Dordrecht, pp. 253-267.

Bechtel, W., and Abrahamsen, A., 1991. Connectionism and the mind., Blackwell, Oxford, 349 pp.

Bodamer, J., 1947. Die Prosop-agnosie. Arch. Psychiatr. Nervenkrankh., 179: 6-54 (translated in part in English by Ellis, H.D., and Florence, M., 1990. Cognit. Neuropsychol., 7: 81-105).

Brédart, S., 1993a. Retrieval failures in face naming. Memory, 1: 351-356.

Brédart, S., and Valentine, T., 1992. From Monroe to Moreau: An analysis of face naming errors. Cognition, 45: 187-223.

Brédart, S., and Valentine, T., 1993. Naming equally familiar faces of more or less familiar individuals. Communication at Faces '93, Cardiff.

Brennen, T., Baguley, T., Bright, J., and Bruce, V., 1990. Resolving semantically-induced tip-of-the-tongue states for proper nouns. Mem. and Cogn., 18: 339-347.

Bruce, V., 1979. Searching for politicians: an information-processing approach to face recognition. Q. J. Exp. Psychol., 31: 373-396.

Bruce, V., 1986. Recognising familiar faces. In: H. Ellis, M. Jeeves, F. Newcombe and A. Young (Editors), Aspects of Face Processing, Nijhoff, Dordrecht, pp. 107-117.

Bruce, V., 1988. Recognising Faces. Lawrence Erlbaum Associates, Hove and London, 154 pp.

Bruce, V., and Burton, M. (Editors), 1992. Processing Images of Faces. Ablex, Norwood, NJ, 255 pp.

Bruce, V., Cowey, A., Ellis, A.W., and Perrett, D.I. (Editors), 1992. Processing the Facial Image. Clarendon Press, Oxford, 132 pp.

Bruce, V., Ellis, H.D., Gibling, F., and Young, A.W., (1987). Parallel processing of the sex and familiarity of faces. Can. J. Psychol., 41: 510-520.

Bruce, V., and Valentine, T., 1985. Identity priming in the recognition of familiar faces. Brit. J. Psychol., 76: 373-383.

Bruce, V., and Valentine, T., 1986. Semantic priming of familiar faces. Quart. J. Exp. Psychol., 38A: 125-150.

Bruce, V., and Young, A.W., 1986. Understanding face recognition. Brit. J. Psychol., 77: 305-327.

Brunas, J., Young, A.W., and Ellis, A.W., 1990. Repetition priming from incomplete faces: evidence for part to whole completion. Brit. J. Psychol., 81: 43-56.

Bruyer, R. (Editor), 1986. The Neuropsychology of Face Perception and Facial Expression. Lawrence Erlbaum Associates, Hillsdale, NJ, 309 pp.

Bruyer, R., 1987. Les Mécanismes de Reconnaissance des Visages. Presses Universitaires de Grenoble, Grenoble, 119 pp.

Bruyer, R., 1989. Disorders of face processing. In: A.W. Young and H.D. Ellis (Editors), Handbook of Research on Face Processing, North-Holland, Amsterdam, pp. 437-473.

Bruyer, R., 1990. La Reconnaissance des Visages. Delachaux & Niestlé, Neuchâtel, 149 pp.

Bruyer, R., 1991. Covert face recognition in prosopagnosia: a review. Brain & Cogn., 15: 223-235

Bruyer, R., 1993. Failures of face processing in normal and brain-damaged subjects. In: F. Boller and J. Grafman (Editors), Handbook of Neuropsychology (vol. VIII), Elsevier, Amsterdam, pp. 409-433.

Bruyer, R., 1994. Face recognition. In: V.S. Ramachandran (Editor), Encyclopedia of Human Behavior, Academic Press, San Diego, in press.

Bruyer, R., Galvez, C., and Prairial, C., 1993. Effect of disorientation on visual analysis, familiarity decision and semantic decision on faces. Brit. J. Psychol., 84: 433-441.

Bruyer, R., Laterre, C., Seron, X., Feyereisen, P., Strypstein, E., Pierrard, E., and Rectem, D., 1983. A case of prosopagnosia with some preserved covert remembrance of familiar faces. Brain and Cogn., 2: 257-284.

Bruyer, R., and Scailquin, J.C., 1994. Person recognition and aging: the cognitive status of addresses, an empirical question. Intern. J. Psychol., in press.

Bruyer, R., Van der Linden, M., Lodewijck, M., Nelles, B., Schils, J-P., Schweich, M., and Brédart, S. Age differences in putting names and occupations to faces? Arch. Psychol., 60: 243-257

Burton, A.M., Bruce, V., and Johnston, R.A., 1990. Understanding face recognition with an interactive activation model. Brit. J. Psychol., 81: 361-380.

Burton, A.M., and Bruce, V. 1992. I recognize your face but I can't remember your name: A simple explanation? Brit. J. Psychol., 83: 45-60.

Burton, A.M., and Bruce, V. 1993. Naming faces and naming names: Exploring an interactive activation model of person recognition. Memory, 1: 457-480.

Burton, A.M., Young, A.W., Bruce, V., Johnston, R.A., and Ellis, A.W. 1991. Understanding covert recognition. Cognition, 39: 130-166.

Campbell, R., Landis, T., and Regard, M., 1986. Face recognition of lipreading: a neurological dissociation. Brain, 109: 509-521.

Campbell, R., Heywood, C.A., Cowey, A., Regard, M., and Landis, T., 1990. Sensitivity to eye gaze in prosopagnosic patients and monkeys with superior temporal sulcus ablation. Neuropsychologia, 28: 1123-1142.

Carney, R., and Temple, C.M., 1993. Prosopanomia? A possible category-specific anomia for faces. Cognit. Neuropsychol., 10: 185-195.

Cohen, G., 1990. Why is it difficult to put names to faces? Brit. J. Psychol., 81: 287-298.

Cohen, G., and Faulkner, D., 1986. Memory for proper names: age differences in retrieval. Brit. J. Develop. Psychol., 4: 187-197.

Damasio, A.R., Damasio, H., and Van Hoesen, G.W., 1982. Prosopagnosia: anatomic basis and behavioral mechanisms. Neurology, 32: 331-341.

Damasio, A.R., Tranel, D., and Damasio, H., 1990. Varieties of face agnosia: different neuropsychological profiles and neural substrates. J. Clin. Exper. Neuropsychol., 12: p. 66.

Davidoff, J. and Landis, T., 1990. Recognition of unfamiliar faces in prosopagnosia. Neuropsychologia, 28: 1143-1161.

De Haan, E.H.F., and Hay, D.C., 1986. The matching of famous and unknown faces, given either the internal or the external features: a study on patients with unilateral brain lesions. In: H. Ellis, M. Jeeves, F. Newcombe and A. Young (Editors), Aspects of Face Processing, Nijhoff, Dordrecht, pp. 302-309.

De Haan, E.H.F., Young, A.W., and Newcombe, F., 1987a. Face recognition without awareness. Cognit. Neuropsychol., 4: 385-415.

De Haan, E.H.F., Young, A.W., and Newcombe, F. 1987b. Faces interfere with name classification in a prosopagnosic patient. Cortex, 23: 309-316.

De Haan, E.H.F., Young, A.W., and Newcombe, F., 1991. A dissociation between the sense of familiarity and access to semantic information concerning familiar people. Europ. J. Cognit. Psychol., 3: 51-67.

De Renzi, E., 1986a. Prosopagnosia in two patients with CTscan evidence of damage confined to the right hemisphere. Neuropsychologia, 24: 385-389.

De Renzi, E., 1986b. Current issues on prosopagnosia. In: H.D. Ellis, M.A. Jeeves, F. Newcombe and A.W. Young (Editors), Aspects of Face Processing, Nijhoff, Dordrecht, pp. 243-252.

De Renzi, E., Bonacini, M., and Faglioni, P., 1989. Right posterior brain-damaged patients are poor at assessing the age of a face. Neuropsychologia, 27: 839-848.

De Renzi, E., Faglioni, P., Grossi, D., and Nichelli, P., 1991. Apperceptive and associative forms of prosopagnosia. Cortex, 27: 213-221.

Diamond, R., and Carey, S., 1986. Why faces are and are not special: an effect of expertise. J. Exp. Psychol.: Gen., 115: 107-117.

Ellis, A.W., Young, A.W., Flude, B.M., and Hay, D.C., 1987. Repetition priming of face recognition. Quart. J. Exp. Psychol., 39A: 193-210.

Ellis, H.D., 1983. The role of the right hemisphere in face perception. In: A.W. Young (Editor), Functions of the Right Cerebral Hemisphere, Academic Press, London, pp. 33-64.

Ellis, H.D., 1986. Introduction: processes underlying face recognition. In: R. Bruyer (Editor), The Neuropsychology of Face Perception and Facial Expression. Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 1-27.

Ellis, H.D., Jeeves, M.A., Newcombe, F., and Young, A.W. (Editors), 1986. Aspects of Face Processing. Nijhoff, Dordrecht, 509 pp.

Ellis, H.D., Shepherd, J.W., and Davies, G.M., 1979. Identification of familiar and unfamiliar faces from internal and external features: some implications for theories of face recognition. Perception, 8: 431-439.

Ellis, H.D., and Young, A.W., 1990. Accounting for delusional misidentifications. Brit. J. Psychiatr., 157: 239-248.

Etcoff, N.L., Freeman, R., and Cave, K.R. 1991. Can we lose memories of faces? Content specificity and awareness in a prosopagnosic. J. Cognit. Neuroscience, 3: 25-41.

Farah, M.J., 1990. Visual Agnosia: Disorders of Object Recognition and What They Tell Us About Normal Vision, MIT Press, Cambridge, MA, 184 pp.

Farah, M.J., 1991. Patterns of co-occurrence among the associate agnosias: implications for visual object representation. Cognit. Neuropsychol., 8: 1-19.

Flude, B.M., Ellis, A.W., and Kay, J., 1989. Face processing and name retrieval in an anomic aphasic: names are stored separately from semantic information about people. Brain and Cogn., 11: 60-72.

Hanley, J.R., and Cowell, E.S., 1988. The effects of different types of recognition cues on the recall of names of famous faces. Mem. and Cogn., 16: 545-555.

Hanley, J.R., Young, A.W., and Pearson, N.A., 1989. Defective recognition of familiar people. Cognit. Neuropsychol., 6: 179-210.

Hay, D.C., and Young, A.W., 1982. The human face. In: A.W. Ellis (Editor), Normality and Pathology in Cognitive Functions, Academic Press, New York, pp. 173-202.

Hay, D.C., Young, A.W., and Ellis, A.W.,1991. Routes through the face recognition system. Quart. J. Exp. Psychol., 43A: 761-791.

Hosie, J.A., Ellis, H.D., and Haig, N.D., 1988. The effect of feature displacement on the perception of well-known faces. Perception, 17: 461-474.

Johnson, M.H., and Morton, J., 1991. Biology and Cognitive Development: the case of face recognition. Blackwell, Oxford, 180 pp.

Johnston, R.A., and Bruce, V., 1990. Lost properties? Retrieval differences between name codes and semantic codes for familiar people. Psychol. Res., 52: 62-67.

Landis, T., Cummings, J.L., Christen, L., Bogen, J.E., and Imhof, H.G., 1986. Are unilateral right posterior cerebral lesions sufficient to cause prosopagnosia? Clinical and radiological findings in six additional patients. Cortex, 22: 243-252.

Landis, T., Regard, M., Bliestle, A., and Leihues, P., 1988. Prosopagnosia and agnosia for noncanonical views. Brain, 111: 1287-1297.

Lissauer, H., 1890. Ein Fall von Seelenblindheit nebst einem Beitrage zur Theorie deselben. Arch. Psychiat. Nervenkrankheit., 21: 222-270 (English translation by Jackson, M., 1988. Cognit. Neuropsychol., 5: 157-192).

Lucchelli, F., and De Renzi, E., 1992. Proper name anomia. Cortex, 28: 221-230.

Malone, D.R., Morris, H.H., Kay, M.C., and Levin, H.S., 1982. Prosopagnosia: a double dissociation between the recognition of familiar and unfamiliar faces. J. Neurol. Neurosurg. Psychiatr., 45: 820-822.

McKenna, P., and Warrington, E.K., 1980. Testing for nominal dysphasia. J. Neurol. Neurosurg. Psychiatr., 43: 781-788.

McNeil, J.E., and Warrington, E.K., 1991. Prosopagnosia: a reclassification. Quart. J. Exp. Psychol., 43A: 267-287.

McNeil, J.E., and Warrington, E.K., 1993. Prosopagnosia: a face-specific disorder. Quart. J. Exp. Psychol., 46A: 1-10.

McWeeny, K.H., Young, A.W., Hay, D.C., and Ellis, A.W., 1987. Putting names to faces. Brit. J. Psychol., 78: 143-149.

Meadows, J.C., 1974. The anatomical basis of prosopagnosia. J. Neurol. Neurosurg. Psychiatr., 37: 489-501.

Michel, F., Poncet, M., and Signoret, J.L., 1989. Les lésions responsables de la prosopagnosie sont-elles toujours bilatérales? Rev. Neurol. (Paris), 146: 764-770.

Morton, J., 1969. Interaction of information in word recognition. Psychol. Rev., 76: 165-178.

Morton, J., and Patterson, K., 1980. A new attempt at an interpretation, or, an attempt at a new interpretation. In: M. Coltheart, K. Patterson and J.C. Marshall (Editors), Deep Dyslexia, Routledge and Kegan Paul, London, pp. 91-118.

Newcombe, F., Young, A.W., and De Haan, E.H.F. 1989. Prosopagnosia and object agnosia without covert recognition. Neuropsychologia, 27: 179-191.

Parry, F.M., Young, A.W., Saul, J.S.M., and Moss, A., 1991. Dissociable face processing impairments after brain injury. J. Clin. Exp. Neuropsychol., 13: 545-558.

Perrett, D.I., Mistlin, A.J., Chitty, A.J., Harries, M., Newcombe, F., de Haan, E., 1988. Neuronal mechanisms of face perception and their pathology. In: C. Kennard and F. Clifford-Rose (Editors), Physiological Aspects of Clinical Neuro-Ophtalmology, Chapman and Hall, London, pp. 137-154.

Ratcliff, G., and Newcombe, F., 1982. Object recognition: some deductions from the clinical evidence. In: A.W. Ellis (Editor), Normality and Pathology in Cognitive Functions, Academic Press, New York, pp. 147-171.

Renault, B., Signoret, J.L., Bebruille, B., Breton, F., and Bolgert, F. 1989. Brain potentials reveal covert facial recognition of faces in prosopagosia. Neuropsychologia, 27: 905-912.

Rhodes, G., 1985. Lateralized processes in face recognition. Brit. J. Psychol., 76: 249-271.

Rhodes, G., Brake, S., and Atkinson, A., 1993. What's lost in inverted faces? Cognition, 47: 25-57.

Rhodes, G., Brennan, S., and Carey, S., 1987. Identification and ratings of caricatures: implications for mental representations of faces. Cognitive Psychol., 19: 473-497.

Rhodes, G. and Tremewan, T., The Simon then Garfunkel effect: semantic priming, sensitivity, and the modularity of face recognition. Cogn. Psychol., 25: 147-187.

Rumelhart, D.E., and McClelland, J.L. 1986. Parallel Distributed Processing. Vol. 1. Foundations. MIT Press, Cambridge, MA, 547 pp.

Rizzo, M., Hurtig, R., and Damasio, A.R. 1987. The role of scanpaths in facial recognition and learning. Annals Neurol., 22: 41-45.

Schweich, M., and Bruyer, R., 1992. Elaboration du contexte dans la reconnaissance de visages chez des sujets normaux et des patients prosopagnosiques. Rev. Neuropsychol., 2: 273-304.

Schweich, M., and Bruyer, R., 1993. Heterogeneity in the cognitive manifestations of prosopagnosia: the study of a group of isolated cases. Cognit. Neuropsychol., 10: 529-547.

Schweich, M., Van der Linden, M., Brédart, S., Bruyer, R., Nelles, B., and Schils, J.P., 1992. Daily-life difficulties in person recognition reported by young and elderly subjects. Appl. Cogn. Psychol., 6: 161-172.

Semenza, C., and Zettin, M., 1988. Generating proper names: a case of selective inability. Cogn. Neuropsychol., 5: 771-721.

Semenza, C., and Zettin, M., 1989. Evidence from aphasia of proper names as pure referring expressions. Nature, 342: 678-679.

Sergent, J., 1984. An investigation into component and configural processes underlying face perception. Brit. J. Psychol., 75: 221-242.

Sergent, J., 1986. Microgenesis of face perception. In: H.D. Ellis, M.A. Jeeves, F. Newcombe and A.W. Young (Editors), Aspects of Face Processing, Nijhoff, Dordrecht, pp. 17-33.

Sergent, J., and Poncet, M., 1990. From covert recognition of faces in a prosopagnosic patient. Brain, 113: 989-1004.

Shallice, T., and Kartsounis, L.D., 1993. Selective impairment of retrieving people's names: a category specific disorder? Cortex, 29: 281-291.

Shepherd, J., Davies, G., and Ellis, H., 1981. Studies of cue saliency. In: G. Davies, H. Ellis and J. Shepherd (Editors), Perceiving and Remembering Faces, Academic Press, London, pp. 105-131.

Small, M., 1988. Visual evoked potentials in a patient with prosopagnosia. Electoencephal. Clin. Neurophysiol., 71: 10-16.

Stanhope, N., and Cohen, G. 1993. Retrieval of proper names: Testing the models. Brit. J. Psychol., 84: 51-65.

Tiberghien, G., and Clerc, I., 1986. The cognitive locus of prosopagnosia. In: R. Bruyer (Editor), The Neuropsychology of Face Perception and Facial Expression, Lawrence Erlbaum, Hillsdale, NJ, pp. 39-62.

Tranel, D., and Damasio, A.R., 1985. Knowledge without awareness: An autonomic index of facial recognition by prosopagnosics. Science, 228: 1453-1454.

Tranel, D., and Damasio, A.R., 1988. Non-conscious face recognition in patients with face agnosia. Beh. Brain Res., 30: 235-249.

Tranel, D., Damasio, A.R., and Damasio, H., 1988. Intact recognition of facial expression, gender, and age in patients with impaired recognition of face identity. Neurology, 38: 690-696.

Valentine, T., 1991. A unified account of the effects of distinctiveness, inversion and race in face recognition. Quart. J. Exp. Psychol., 43A: 161-204.

Valentine, T., Brédart, S., Lawson, R., and Ward, G., 1991. What's in a name? Access to information from people's names. Europ. J. Cogn. Psychol., 3: 147-176.

Valentine, T., Brennen, T., and Brédart, S., 1994. On the importance of being Ernest: The cognitive psychology of proper Names. Harvester-Wheatheaf, London, in press.

Wallace, M.A., and Farah, M.J. 1992. Savings in relearning face-name associations as evidence for "covert recognition" in prosopagnosia. J. Cognit. Neuroscience, 4: 150-154

Warren, C., and Morton, J., 1982. The effects of priming on picture recognition. Brit. J. Psychol., 73: 117-129.

Young, A.W., and De Haan, E.H.F., 1988. Boundaries of covert recognition in prosopagnosia. Cognit. Neuropsychol., 5: 317-336.

Young, A.W., Ellis, A.W., and Flude, B., 1988. Accessing stored information about familiar people. Psychol. Res., 50: 111-115.

Young, A.W., and Ellis, H.D. (Editors), 1989a. Handbook of Research on Face Processing. North-Holland, Amsterdam, 605 pp.

Young, A.W., and Ellis, H.D., 1989b. Semantic processing. In: A.W. Young and H.D. Ellis (Editors), Handbook of Research on Face Processing, North-Holland, Amsterdam, pp. 235-262.

Young, A.W., and Ellis, H.D., 1989c. Childhood prosopagnosia. Brain and Cogn., 9: 16-47.

Young, A.W., Ellis, H.D., Szulecka, T.K., and De Pauw, K.W., 1990. Face processing impairments and delusional misidentification. Behav. Neurol., 3: 153-168.

Young, A.W., Hay, D.C., and Ellis, A.W., 1985a. The faces that launched a thousand slips: everyday difficulties and errors in recognizing people. Brit. J. Psychol., 76: 495-523.

Young, A.W., Hay, D.C., McWeeny, K.H., Flude, B.M., and Ellis, A.W., 1985b. Matching familiar and unfamiliar faces on internal and external features. Perception, 14: 737-746.

Young, A.W., Hellawell, D., and De Haan, E.H.F., 1988. Cross-domain semantic priming in normal subjects and a prosopagnosic patient. Quart. J. Exp. Psychol., 40A: 561-580.

Young, A.W., McWeeny, K.H., Hay, D.C., and Ellis, A.W., 1986a. Access to identity-specific semantic codes from familiar faces. Quart. J. Exp. Psychol., 38A: 271-295.

Young, A.W., McWeeny, K.H., Ellis, A.W., and Hay, D.C., 1986b. Naming and categorising faces and written names. Quart. J. Exp. Psychol., 38A: 297-318.

Young, A.W., Ellis, A.W., Flude, B.M., McWeeny, K.H., and Hay, D.C. 1986c. Face-name interference. J Exp Psychol. Human Perception and Performance, 12: 466-475.

FIGURE CAPTIONS

FIGURE 1 - Bruce and Young's (1986) model of face recognition (reproduced with the permission of the British Psychological Society and of the authors).

FIGURE 2. - Burton, Bruce & Johnston's (1990) interactive activation model of face recognition (adapted and reproduced with the permission of the British Psychological Society and of the authors).

FIGURE 3. - The semantic priming effect in Burton, Bruce and Johnston's model (adapted and reproduced with the permission of the British Psychological Society and of the authors)