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CHAPTER FOUR

Visual processing and the dissociation between biological and man-made categories

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INTRODUCTION

The observation and detailed characterisation of selective impairments affecting particular cognitive areas in brain-damaged individuals can be used to inform the anatomical and functional architecture of normal cognition. Among the most striking forms of selective impairments to have been documented by neuropsychology since the mid-1980s are those that selectively affect the processing of objects from particular semantic categories while sparing objects from other categories. Most often, the semantic boundary that separates the affected categories from those that are spared distinguishes between biological and non-biological (i.e. man-made) items. In this chapter, we will review evidence from cases with category-specific visual recognition impairments that are attributable to a deficit in visual rather than semantic processing. Evidence from these studies will be used to speculate on the organisation of the visual system in the intact brain and on how this organisation interacts with the differing features of biological and non-biological semantic categories to eventually produce categorical effects in visual object recognition.

In the first papers to appear on category specific impairments, the dissociations between biological and non-biological categories in brain-damaged patients were more or less taken as an *a priori* sign that the functional deficit concerned semantic memory. For example, as an argument against the possibility that the category-specific deficits they observed in their patients were due to visual problems, Warrington and Shallice (1984 p. 847) stated that "category specificity findings are very difficult to explain in terms of some form of visual processing deficit". McCarthy and Warrington (1988 p. 428) added "for a category specific deficit to arise in the first place it is necessary that the information should have already been categorised along a semantic dimension". From these postulates it appeared unlikely, or even impossible, that presemantic deficits, such as those affecting vision, could ever result in category-specific impairments.

This view soon had to be revised, however, with the publication of cases with category-specific impairments that were quite clearly the consequence of deficits concerning visual processing rather than semantic memory. As a shorthand, we will refer to these cases as suffering from category-specific visual agnosia, or CSVA. To properly understand the investigations that were conducted on these cases, and to assess their possible implications for visual processing, we will first present an overview of current basic assumptions about the organisation of the visual recognition system.

VISUAL OBJECT PROCESSING

Although surface features such as colour might facilitate visual object recognition to some degree for object classes possessing characteristic surface properties, such as biological objects (Humphrey, Goodale, Jacobson, & Servos, 1994; Price & Humphreys, 1989; Wurm, Legge, Isenberg, & Luebker, 1993), it appears that the most fundamental information for visual object recognition is shape (Biederman & Ju, 1988; Marr & Nishihara, 1978). Shape processing is a complex issue and its intricacies are beyond the scope of this chapter (see Feldman & Richards [1998] and Hoffman & Singh [1997] for recent reviews). Most authors agree on a broad division of visual processes involved in visual object recognition along two main sequential stages and this simple division will be sufficient for the present purpose.

The first stage is that of perceptual encoding, which is concerned with registering the properties of the image projected on the retina and in constructing an adequate perceptual representation of seen objects. One main function of this processing stage is to discriminate between visual objects. It is widely assumed that this stage is responsible for performance in perceptual discrimination or perceptual judgement tasks. Brain-damaged individuals with so-called apperceptive agnosia (Lissauer, 1890/1988) or visual form agnosia (Benson & Greenberg, 1969; Milner & Heywood, 1989), for instance, would suffer from a deficit at the stage of perceptual encoding.

The second visual processing stage is that of structural descriptions, i.e. a long-term memory store holding information on the visual appearance of objects. Such a memory system is assumed to be required to insure object constancy, i.e. the stability of object recognition across changes in the retinal

an object and central repres
of structural descriptions is generally agreed to be the basis for performance in such tasks as object decisions, where observers must distinguish between visual instances of real objects and those of invented or meaningless objects (e.g. made of juxtaposed parts taken from distinct real objects; Figure 4.1). As will be described below, most patients with CSVA suffer from a deficit affecting the stage of structural descriptions.

Beyond visual processing, two other stages must be assumed for a complete account of visual object recognition. One is semantic memory, which is a long-term store holding our knowledge of the meanings of objects. Along with other authors (e.g. Coltheart et al. 1998; Humphreys, Lamote, & Lloyd-Jones, 1995; Humphreys, Riddoch, & Quinlan, 1988), we will assume that the information that is kept in semantic memory pertains mainly to non-sensory information (often referred to as functional, associative, or encyclopaedic object properties), such as what an object is for, what it does, where it lives, etc, and that sensory information is stored in modality-specific and code-specific memory systems such as structural desciptions in the case of vision. This implies, among other things, that one must refer to the structural description system to answer verbal questions about specifically visual properties of objects (e.g. "do cats have pointed ears?"). In visual object recognition, access to semantic memory, which permits the assignment of meaning to the stimulus, is via the structural description system. Finally, from semantic memory it is possible to access phonological representations of object names to permit the naming of visually presented objects.

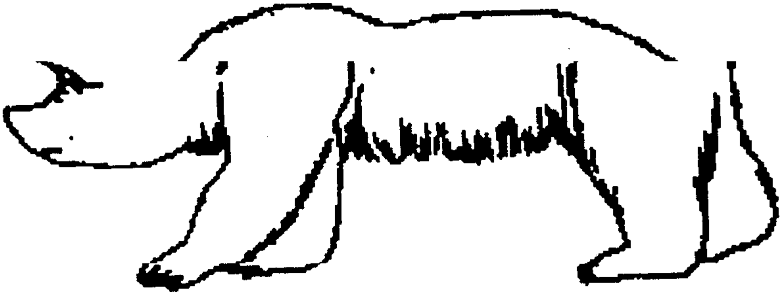

Figure 4.1. Example of a negative item that might be used in the object decision task.

Neuropsychological evidence indicates that both semantic memory and phonological representations can be selectively affected by brain damage and, in some instances, these deficits can result in category specific impairments.

One final but crucial assumption regarding the organisation of the visual recognition system is that the stages involved interact with one another in a cascaded fashion (McClelland, 1979), meaning that the flow of information between successive stages is continuous and independent of whether any stage has settled into a stable solution. One key implication of this is that variables that specifically affect separate stages of processing might nevertheless have interactive effects on performance (Humphreys et al., 1995). As will be seen, this property is important for accounting for the observations described below.

CATEGORY-SPECIFIC VISUAL AGNOSIA (CSVA)

Possibly the first CSVA patient to have been reported in the neuropsychological literature is HJA, who showed poorer performance in the visual recognition of biological than non-biological objects (Riddoch & Humphreys, 1987a; see also Riddoch et al, 1999). This patient was impaired in the integration of the local visual features of objects into a global unit, although he retained good knowledge of the visual and semantic properties of objects (Humphreys & Riddoch, 1987; Riddoch & Humphreys, 1987a). This means that HJA's visual recognition disorder, as well as its category specificity, were a function of a visual deficit affecting perceptual encoding, and not of an impaired semantic memory. It appears the case of HJA has gone relatively unnoticed in the literature on category-specific impairments, possibly because of the emphasis that was placed on a detailed characterisation of his visual deficit rather than on its category specificity, which remained relatively unexplored. Other reports of brain-damaged individuals with category specific visual recognition impairments caused by a presemantic deficit soon followed, however.

Apart from HJA, there are nine other cases of category-specific impairments that are quite clearly attributable to functional damage preceding the semantic system.[1] These are, in alphabetical order: ELM (Arguin, Bub, & Dudek, 1996a; Dixon & Arguin, 1999; Dixon, Bub, & Arguin, 1997, 1998; Dudek, Arguin, & Bub, 1994; Dudek, Arguin, Dixon, & Bub, 1997); Felicia (De Renzi & Lucchelli, 1994); Helga (Mauri et al., 1994); Giuletta (Sartori et

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[1] Several other brain-damaged cases with category-specific impairments reported in the literature could possibly fit within this group. However, either their impairments are complicated by word comprehension impairments, suggesting a semantic memory deficit, or the testing conducted was insufficient to point unambiguously to a presemantic visual deficit as the cause of these impairments.

al., 1993a); IL (Arguin et al., 1996b); JB (Humphreys et al., 1988; Riddoch & Humphreys, 1987b); LH (Farah, Hammond, Mehta, & Ratcliff, 1989; Farah, McMullen, & Meyer, 1991; Etcoff, Freeman, & Cave, 1991); Michelangelo (Mauri et al., 1994; Sartori, Coltheart, Miozzo & Job, 1995; Sartori & Job, 1988; Sartori, Miozzo, & Job; 1993b); and SRB (Forde et al., 1997).

Several important generalisations can be made from these patients. Each of them shows an impairment that is either selective to biological objects (animals, fruit and vegetables, plants, insects, etc.) or significantly greater for these categories than for non-biological objects. In addition, in cases where this has been documented, patients can often report the superordinate category (e.g. animal) of visual objects they fail to identify by their basic level names (e.g. cat). One important point to note is that the disorder is often accompanied by a recognition impairment for some categories of man-made objects, in particular musical instrument, and makes of car (see also Basso, Capitani, & Laiacona, 1988; Damasio, 1990; Farah, 1991; Humphreys & Riddoch, 1987b; Warrington & Shallice, 1984). Thus, although the biological/non-biological distinction is a convenient shorthand to refer to the categories that are affected versus those that are spared, it appears it does not completely account for the dissociations that are observed (see, however, Caramazza & Shelton, 1998). This suggests that some fundamental object property that is not captured by the distinction between biological and man-made objects may be involved in, and perhaps responsible for these dissociations. We will return to this issue later.

Another important trait that is common to most patients with CSVA is that their brain damage can involve the inferior temporal lobe of either the left or right hemisphere, or it can be bilateral. These lesions are often caused by herpes simplex encephalitis. With respect to lesion localisation, exceptional cases are JB, who showed a left parieto-occipital lesion, and Helga, who suffered from Alzheimer's dementia and showed diffuse cortical atrophy on CT scan.

One key feature in the above cases is that, as far as their investigators could determine, visual perceptual encoding functions were normal. This is at variance with HJA, who was clearly impaired at this level. Rather, a central issue in the more recent cases was access to stored structural descriptions. Access from vision is assessed by tests such as the object decision task, where subjects have to discriminate between pictures of real versus unreal (invented) but plausible objects. Access from language is assessed by object recognition from a verbal description or by probe questions about the structural properties of an object referred to by its name. All the above cases show some form of impairment affecting the retrieval of stored visual information specific to biological objects. Except for JB, all of them show impaired retrieval of stored visual knowledge for biological objects from both visual and verbal input, thereby suggesting functional damage to the structural description system. In the case of JB, access to structural descriptions from vision was normal but was impaired from a verbal input. This suggests that the deficit in JB concerns the links between structural descriptions and semantic memory.

In striking contrast to their performance in tests probing stored knowledge of the structural properties of biological objects, all of these patients perform either normally or at least significantly better on similar tasks using man-made objects. The evidence also suggests intact or relatively spared semantic memory in these cases because they demonstrate at least adequate non-sensory knowledge of both biological and non-biological objects.

One obvious question that must be asked with respect to the above CSVA cases is "what are the features of the visual recognition system and/or the differences between biological and non-biological objects that would be sufficient to account for the categorical dissociations observed?" Several propositions have been put forward to answer this question.

Accounts of CSVA[2]

Visual recognition in general is to some degree affected by factors such as the frequency or the visual complexity of the item or our familiarity with it. From this, Stewart, Parkin, and Hunkin (1992) as well as Funnell and Sheridan (1992), argued that, when left uncontrolled, such factors could artifactually cause performance dissociations between the processing of biological and man-made objects. In support of this argument, Stewart et al. (1992) reported patient HO, who was poorer at the visual identification of pictures of biological than non-biological items. However, when items from these broad categories were matched carefully according to name frequency, visual complexity, and familiarity (Snodgrass & Vanderwart, 1980), no residual effect of semantic category remained in the visual identification performance of the patient. A similar study was reported by Funnell and Sheridan (1992) whose patient, SL, exhibited a dissociation between biological and man-made objects that was, in fact, entirely determined by differences in familiarity. The explanation of the biological/non-biological dissociation as an artifact of uncontrolled trivial factors defended by Funnell and Sheridan (1992) and by Stewart et al. (1992) does not apply to the CSVA cases listed above, however. Indeed, in each of these cases, the dissociation between visual recognition performance for biological and man-made items remains when the effects of frequency, familiarity, and complexity are either controlled or partialled out by regression analysis.

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[2] This review is by no means exhaustive. Its main purposes are to highlight the different directions authors have taken in reasoning about the possible causes of category-specific impairments and to review what appear as the most relevant alternatives in the context of CSVA. The reader should consult Forde and Humphreys (1999) for a current discussion of the various accounts of category specific impairments.

If the categorical dissociation observed in a particular brain-damaged patient cannot be the trivial consequence of uncontrolled factors such as those discussed by Stewart et al. (1992) and by Funnell and Sheridan (1992), it is tempting to believe that the biological and man-made items used in testing are comparable in every possible respect, save the semantic category they belong to. Such a belief inevitably leads to the assumption that category-specific impairments can be explained only by a categorically organised perceptual processing system. Sartori and Job (1988) have defended such a possibility to account for the category specificity of the visual agnosia of their patient, Michelangelo (see also Caramazza, 1998; Caramazza & Shelton, 1998; Samson, Pillon, & De Wilde, 1998; for similar views regarding patients with category-specific impairments caused by a deficit of semantic memory). More precisely, the argument proposed by Sartori and Job is that a component of Michelangelo's structural description system that was specialised for the representation of biological objects has been damaged whereas the component concerned with non-biological objects was spared. While this explanation does fit the patient's data, no independent evidence can be cited to support such a categorical organisation of the structural description system. This reduces the explanation proposed to little more than a redescription of the data.

Rather than implicating exclusively the functional architecture of the visual system in the search for an explanation of category-specific effects in CSVA, other authors have also considered the possibility that the very nature of our knowledge of biological and non-biological objects differ. Certainly, the most widely cited such account is that of Warrington and Shallice (1984; but see also Warrington & McCarthy [1987] and Damasio [1990] for variants thereof) who argued that our knowledge of biological objects is more heavily based on sensory than functional properties whereas the opposite would be true of man-made objects. Because of this asymmetry, selective loss of knowledge of sensory properties (such as in most cases of CSVA) would result in greater recognition impairments for biological than non-biological objects. Empirical support the central premises of Warrington and Shallice's (1984) theory has been provided by Farah and McClelland (1991) and by McRae, de Sa, and Seidenberg (1997). Notably, subjects in these studies reported more sensory than functional properties for terms referring to biological objects. These observations have been contested by Caramazza and Shelton (1998), however, on the grounds that the definitions of what should stand as a "functional" property that were used by previous authors were too narrow to fully capture the breadth of our non-sensory knowledge of biological objects. Caramazza and Shelton (1998) also provided an informal report of data suggesting there is no difference in the number of sensory and functional properties for biological objects if a broader notion of what should stand as a functional property is used. Tyler and Moss (1997) as well as Moss, Tyler, Durrant-Peatfield, and Bunn (1998) concur and argue that if one takes into account non-sensory features such as to see, to breathe, to move, etc, there is no shortage of functional features that can be attributed to biological objects.

Another approach to account for CSVA is to seek objective differences between biological and non-biological categories that are more fundamental than the factors discussed by Stewart et al. (1992) and Funnell and Sheridan (1992), and which might interact with particular sensitivies of the visual recognition system in order to produce category specific impairments. In particular, we might note that biological objects are caused by evolution. This means that taxonomically related biological categories will share a large part of their genetic background, and therefore that they will most often have similar visual forms. No such constraint exists for man-made objects, which are manufactured to meet a particular function. This function is the main determinant of their shape (see also De Renzi & Lucchelli [1994] for a related argument) and man-made objects of the same superordinate category (e.g. furniture, tools) might differ substantially in their precise function. This implies that categorically related man-made items might show large differences in their visual appearances. Empirical support for such inferences has been reported by Humphreys et al. (1988), who showed that most semantically related biological objects are more visually similar with each other than non-biological objects, as measured by the numbers of rated common parts and amount of contour overlap. Congruently, McRae et al. (1997) found that normal observers report a greater frequency of co-occurring properties, among them visual properties, between biological than non-biological objects. This suggests that biological items not only share large numbers of their visual features with each other, as shown by Humphreys et al. (1988), but also that they frequently share combinations of visual properties. Moss et al. (1998) as well as Devlin, Gonnerman, Andersen, and Seidenberg (1998) and Gonnerman, Andersen, Devlin, Kempler, and Seidenberg (1998) have all argued similarly and have added that biological items possess fewer distinctive properties, i.e. properties that would uniquely identify them relative to any other object, than man-made items (see also Gaffan & Heywood [1993] for related arguments).

Obviously, the processing demands imposed on the perceptual encoding and structural description stages of visual object recognition will be greater if the items presented are more similar to one another or, alternatively, less distinct. Indeed, such conditions might require a greater level of detail in perceptual analysis, more time to perform relevant discriminations, or even possibly the activation of special visual processes not required otherwise. The above observations can therefore contribute to a satisfactory account of CSVA that makes no appeal to assumptions of fundamental differences between our internal representations of biological and non-biological classes. They might also explain why difficulties in the visual identification of musical instruments and of car makes are often observed in CSVA, as these object categories contain some highly visually similar items.

In support of the role of visual similarity as a determinant of categorical effects in visual object recognition, Humphreys et al. (1988) as well as Gaffan and Heywood (1993), showed that neurologically intact observers perform more poorly in tasks requiring the identification of biological than man-made objects. In fact, as reported by Gaffan and Heywood (1993), even monkeys find it more difficult to discriminate between biological than non-biological items. Clearly, then, some fundamental visual difference exists between both object classes that has a significant impact on the operation of our visual system. Further and more direct support for the role of similarity in the category specificity of CSVA has been reported recently in a study of Forde et al. (1997) in the case of SRB. Forde et al. showed that SRB's visual object naming performance is more strongly determined by the amount of contour overlap (i.e. visual similarity) among objects than by the semantic category (biological versus non-biological) of the item. Furthermore, they report that the category specificity of SRB's agnosia is cancelled in a task where visually presented dogs and cars must be identified at a subordinate level, a task that requires the processing of visual information in a great level of detail for both categories.

Critical appraisal[3]

One important point that must be emphasised regarding the current account of CSVA is that its key explanatory factor is not just visual similarity by itself, but rather within-category similarity; that is, the visual similarity between objects that belong to the same semantic category. Interestingly, when cast against the assumed organisation of the visual recognition system, we note that within-category similarity actually refers to two separate processing stages, one interested in visual shape (i.e. perceptual encoding or structural descriptions), the other in object meaning (semantic memory). In other words, with respect to the stages involved in visual object recognition, within-category similarity does not stand as a single factor but rather as the interaction of two separate factors, namely, visual similarity and semantic relatedness. That interactive effects can occur between two factors that act on separate processing stages is not entirely obvious (McClelland, 1979; Sternberg, 1969; 1998). However, evidence from neurologically intact observers suggests that such interactions do indeed occur in visual object recognition (Humphreys et al., 1988; Vitkovitch, Humphreys, & Lloyd-Jones, 1993). These findings argue that the successive stages involved in visual object recognition interact with one another in a cascade manner (as described earlier

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[3] Some of the issues raised here are further elaborated below.

Humphreys et al., 1995; Lloyd-Jones & Humphreys, 1997) and perhaps more importantly in the present context, they maintain the validity of the "within-category similarity" account of CSVA.

Although, from the above discussion, the problem of CSVA might appear to have been solved, the studies reported so far still suffer from two key limitations. One of them is the exclusive reliance, in visual recognition tasks, on stimuli that refer to real-world objects. In such stimuli, visual shape and meaning are intrinsically tied and each object is unique in various ways, many of which might be unknown to the experimenter (e.g. personal experiences with particular objects). One problem this poses is that the notion of interactive effects of shape similarity and of semantic proximity proposed by the "within-category similarity" account of CSVA cannot be explored fully and that some of its underlying assumptions remain untestable. Indeed, it is practically impossible to entirely dissociate visual similarity from semantic proximity effects using real-world objects. In addition, with such stimuli, one can never be sure that the object categories used (e.g. visually similar versus dissimilar) do not differ on basic aspects such as the type of visual features that define their shapes. In fact, it has been argued that some types of category-specific impairments may take their source in the differing kinds of visual features that define the shapes of objects from various semantic categories (Etcoff et al., 1991). Another problem the exclusive reliance on real-world objects poses is that it is extremely difficult to avoid a degree of circularity between the dissociations observed and the principles that are invoked to account for them. Indeed, clear proof for a theory requires the experimental manipulation of specific key factors that are uncontaminated by other variations, and an examination of their effects. In most studies of CSVA, this is simply not done and the explanations proposed for the semantic category dissociations observed must remain *post hoc*. That is, investigators retrospectively invoke some difference between the spared and impaired semantic categories to account for the observed dissociation without actually being able to provide an experimental test of the effect of that difference. One notable exception to this rule is the study of SRB by Forde et al. (1997), which managed to demonstrate that within-category visual similarity had a greater impact on recognition performance than the biological/man-made distinction.

Another important limitation is that most studies of CSVA are limited in their characterisation of the impairments suffered by the patients. In particular, studies systematically attempt to localise the functional deficit within a broadly defined model of visual object recognition such as that outlined at the beginning of this chapter. They fail, however, to further specify the nature of the disorder affecting the damaged processing stage or connection. In the end, this means that studies of CSVA teach us little about the organisation of the visual object recognition system that we do not already know or assume.

In most cases, then, studies of CSVA are akin to investigations into unusual experimental preparations provided by nature designed to test particular notions about the structure of the world and about independently derived hypotheses on the organisation of the visual system.

There is, however, evidence from one particular case of CSVA that we believe offers some significant advances with respect to the limitations noted here. This case is that of ELM, who has been studied over a period of almost 10 years and who has been the subject of several reports (Arguin et al., 1996a; Dixon & Arguin, 1999; Dixon et al., 1997, 1998; Dudek et al., 1994, 1997). The evidence from these investigations is congruent with the notion of "within-category similarity" as a major factor in explaining CSVA. These, however, provide a complete exploration of the visual similarity by semantic relatedness interaction that is quite unique in both neuropsychology and cognitive psychology. They also provide fundamental indications about the way in which our visual system represents shape that leads to specifications on the notion of visual similarity.

INVESTIGATIONS OF ELM

ELM was an anglophone man born in 1928 who had to retire from his employment as a dispatcher. In 1982, he suffered a first ischaemic cerebral lesion deep in the right mesiotemporal lobe. This left him with mild nominal dysphasia and memory impairment that disappeared some months later. A second neurological episode occurred in 1985 and the CT scan conducted then evidenced bilateral inferior temporal lesions, with the left hemisphere damage substantially more voluminous than that on the right (see Arguin et al., 1996a, Fig. 1). The investigations of his visual agnosia that are discussed below were conducted between 1988 and 1996.

Initial studies of ELM were conducted at the Montreal Neurological Institute by Matthew Decter, in collaboration with doctors. Daniel Bub and Howard Chertkow (Decter, 1992). These revealed the presence of colour agnosia, surface dyslexia and dysgraphia, severe prosopagnosia, and a visual object recognition deficit specific to biological objects. On the line drawings of Snodgrass and Vanderwart (1980), for instance, ELM made 61% errors with biological objects but only 12% with man-made objects. Regression analyses showed that this asymmetry across semantic categories was not a function of confound variables such as familiarity or complexity. It is noteworthy that most of his errors to man-made objects on the Snodgrass and Vanderwart (1980) images concerned musical instruments, which he persistently failed to recognise despite being an amateur musician himself; he also showed major problems in recognising makes of cars. Despite having difficulties in providing the basic level name of biological objects he attempted to identify visually, ELM was consistently able to provide its superordinate category. Studies aimed at specifying the locus of functional impairment showed intact visual perceptual encoding. Notably, the patient was capable of visually recognising man-made objects from unusual viewpoints and was very comfortable at driving his car. Other tests, however, pointed to a damaged structural description system leading to impaired retrieval of stored structural information specific to biological objects. In the object decision task, for instance, ELM was at chance with pictures of animals (error rate of 41%) but excellent with man-made objects (error rate of 7%). On verbal questions probing stored knowledge about the visual appearances of biological objects, he was similarly impaired (45% errors on two-alternative forced-choice questions). By contrast, he did much better on a similar test probing non-sensory knowledge of the same items (error rate of 15%). In summary, then, ELM showed a pattern of cognitive impairments that was, as far as object recognition was concerned, highly similar to that of most other CSVA patients and which appeared to take its source in an impaired structural description system.

Shape processing

The following studies reported by Arguin et al. (1996a) focused on an attempt to provide a more detailed characterisation of the visual shape representation deficit of ELM. This began with a study of the confusion errors the patient made between fruits and vegetables in matching line drawings of these objects to their auditory names (picture–word matching; Arguin et al., 1996a; Experiment 1). The use of fruits and vegetables in this experiment was motivated by the fact that these items were the most visually simple that ELM had difficulty recognising visually, and therefore that shape-based errors with such stimuli would be much easier to interpret than with visually complex biological items like animals or insects. ELM's errors on mismatching trials in this experiment were highly instructive. These errors were heavily concentrated on pairs of items that shared prominent visual shape features with each other. The most notable visual property that determined the errors was elongation. Thus, elongated items (e.g. cucumber and banana) were very often confused with one another and rounded objects (e.g. onion and apple) were confused among themselves. Errors on negative picture–word pairs involving an elongated and a rounded item almost never occurred. Another shape property that appeared determinant was tapering. Thus, negative pairs of items such as pear–lemon, which appear to have been pinched on one or both ends to produce tapered extremities, led to frequent errors. By contrast, there appeared to be no semantic constraint on errors on negative trials. Fruits were readily confused with vegetables, domestic items were confused with exotic ones, fruits that grow on trees were confused with others that grow in bushes, etc. These observations are congruent with the notion that visual similarity, not semantic proximity, is the first determinant of visual recognition errors in CSVA. It was further proposed that ELM's errors on mismatching picture–word pairs were largely determined by the existence of common prominent shape features among items, along with an incapacity to take into account the inconsistency between them on other aspects of their shapes. For instance, it was quite clear that ELM's frequent acceptation of the picture–word pair cucumber–banana was due to their common degree of elongation. However, had he been capable consistently to consider at the same time that cucumbers are typically straight whereas bananas are curved, he would never have accepted such a negative match. From this, it was hypothesised that ELM's main deficit was in processing the full complement of features that are required to uniquely specify the shape of a ✓ particular object, i.e. to distinguish reliably it from any other item that has some shape features in common with it. This hypothesis, referred to as that of a shape integration impairment, was tested in a series of subsequent experiments.

To gain full control over the visual properties of the stimuli used and to avoid the arbitrary constraints imposed by the shapes of real-world objects in this investigation of shape processing in ELM, the subsequent studies by Arguin et al. (1996a) made use of computer-generated two-dimensional (2D) synthetic shapes. These stimuli were filled ellipsoids whose shapes were defined parametrically along the dimensions of elongation (or aspect ratio; defined as the ratio of major over minor axes), curvature (perpendicular to the major axis), and tapering (along the major axis). The rationale for using these particular dimensions, as well as the details of the method used for generating these shapes, can be found in Arguin et al. (1996a). Examples of shapes that can be produced using this scheme are illustrated in Figure 4.2. The feature values of the stimuli aligned along the horizontal axis vary on elongation, items aligned along the vertical axis vary on curvature, and those on the depth axis differ on tapering.

In one picture–word matching experiment using such synthetic stimuli, items had shapes resembling some idealised fruits and vegetables (Arguin et al., 1996a, Experiment 2). In other respects, the paradigm was highly similar to that used in the preceding picture–word matching experiment. The results confirmed one implication of the hypothesis of a shape integration deficit in ELM, namely that error rates on negative trials should decrease with the number of shape features by which the object referred to by the word differed from the picture presented. Thus, ELM accepted negative picture–word pairs on 43.5% of trials if items differed from each other by only one shape feature. However, pairs differing on two shape features were accepted as matching on 25% of trials and those differing along the three shape dimensions of elongation, curvature, and tapering led to an error on only 8.3% of trials. The most significant advances in the study of shape processing in ELM were achieved,

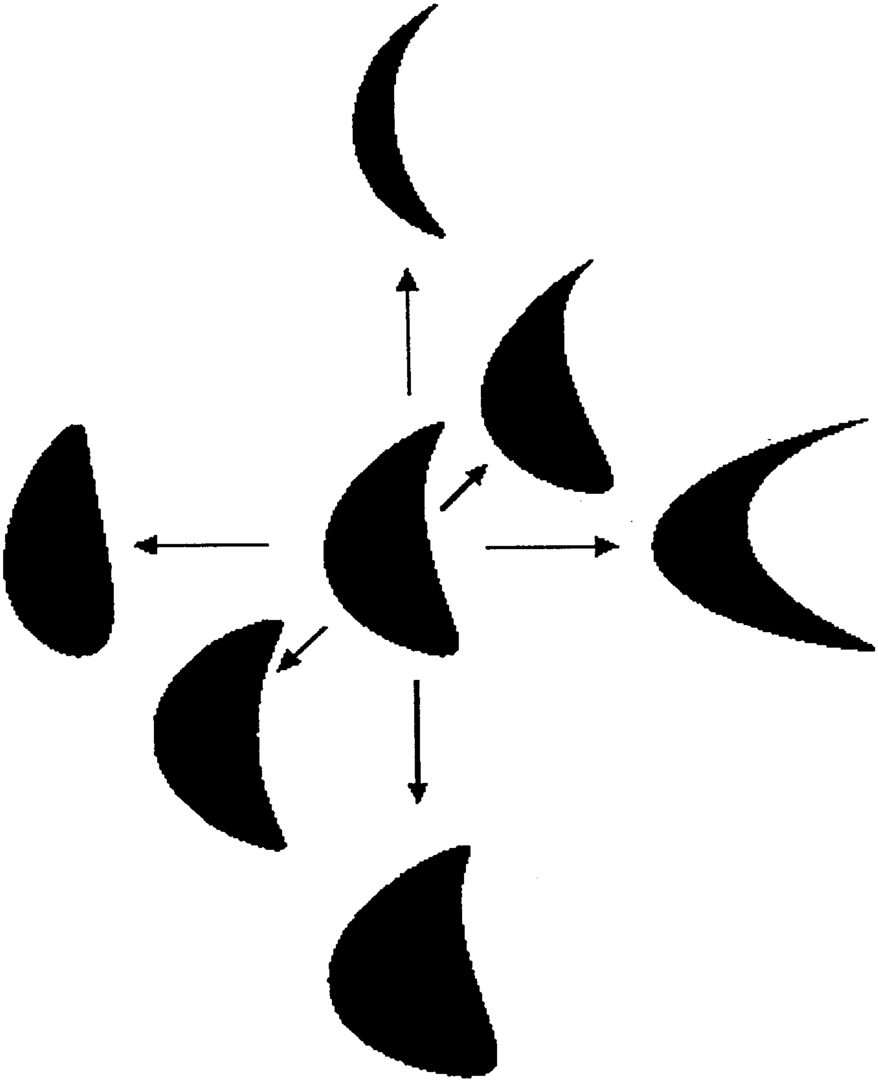

Figure 4.2. Illustration of the dimensions used to define the shapes of stimuli in Arguin et al. (1996a).

however, in tasks where the stimuli used made no explicit reference to the visual appearances of real-world objects.

Possibly the most crucial experiment for a characterisation of the shape-processing deficit in ELM was one where he was required to learn unique and arbitrary associations between sets of four shapes and particular spatial locations on a computer screen (Arguin et al., 1996a, Experiment 4). In a first, learning, phase of the experiment, ELM was exposed to each stimulus of a set placed at its respective corner on the computer screen and asked to remember each shape–location assignment. In a second, test phase, each shape was shown individually at the centre of the computer screen and ELM was simply asked to point to its previously assigned location. In this experiment, two classes of stimulus sets were used. One was called " single dimension sets", and was made of items whose shapes varied either on elongation, curvature, or tapering, but whose values on the other two dimensions remained constant, thereby rendering them irrelevant. This organisation of single dimension sets is illustrated in Figure 4.3a, which shows the locations of each stimulus within a 2D shape space. For instance, the single dimension "elongation" shape set was made of items differing from each other by their feature value on the dimension of elongation, whereas stimuli all were

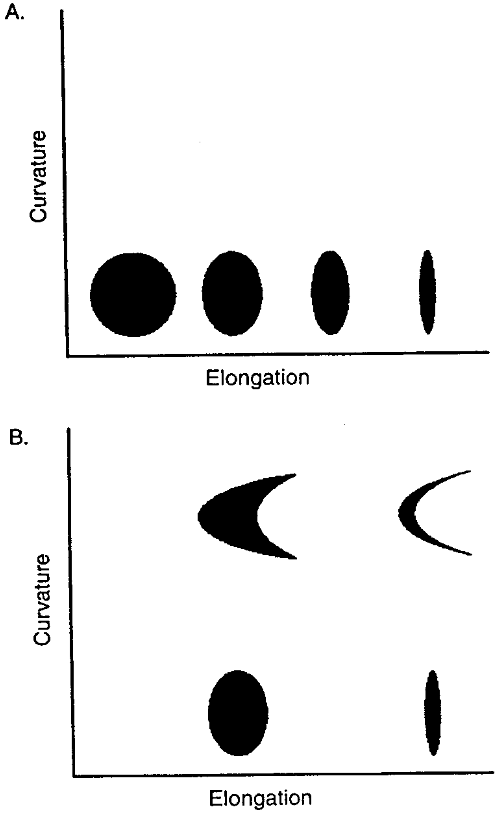

Figure 4.3. Example of stimuli from a single dimension set (A) and a conjunction set (B) along with their respective locations within a two-dimensional shape space.

assigned identical feature values on the dimensions of curvature and tapering. The second class of stimulus sets was called "conjunction sets". Shapes in a conjunction set varied along two dimensions (elongation and curvature, elongation and tapering, or curvature and tapering) in such a way that each item of a set had the same feature value as another item on one of those dimensions, and the same feature value as a third item on the other dimension (Figure 4.3b). All items shared the same feature value on the irrelevant dimension. For instance, the four shapes constituting the "elongation/tapering" conjunction set were produced by crossing two feature values on the dimension of elongation with two feature values on the dimension of tapering; all items shared the same value on curvature. With this stimulus arrangement, the unique identification of a particular item within a conjunction set required the processing of a conjunction of the critical shape features as otherwise, confusions would occur between items that shared feature values with one another. By contrast, proper processing of the single critical feature dimension was sufficient for accurate performance with single dimensions sets. In a patient like ELM, who was assumed to have difficulty in processing combinations of shape features (i.e. shape integration deficit), it was expected that performance would suffer with conjunction relative to single dimension sets. The results supported this prediction, with ELM making about twice as many errors with conjunction shape sets (56.7%) as with single dimension sets (29.2%). The distribution of errors made by ELM with conjunction sets was also congruent with the notion of a shape integration impairment. Thus, on 91.2% of his errors with conjunction sets, ELM pointed to the location of an item that shared one critical feature with the target. In other words, it was extremely rare for ELM to confuse items from ~~with~~ ⁁on ✓ conjunction sets that had no property in common ~~with~~ ⁁on one of the critical dimensions.

Crucially, the conjunction effect observed in the above shape–location learning experiment cannot be accounted for simply on the basis that shapes from conjunction sets were less distinct from one another than those from single dimension sets; in fact, the opposite was true. Thus, the feature values used to construct items from conjunction sets were quite extreme (e.g. straight versus sharply curved) and the differences between these feature values were as great as or greater than just about any feature value difference that existed among shapes from single dimension sets (see Figure 4.3). For instance, in conjunction sets involving the dimension of curvature, curvature differences were as great as the total range of curvature values covered in the "curvature" single dimension set. Congruent with this view, Dixon et al. (1997, experiment 1) later showed that neurologically intact individuals rated shapes from single dimension sets as more visually similar among themselves than those from conjunction sets. What these observations mean is that ELM's particular difficulty with conjunction sets in the shape–location task was not a function of the overall discriminability between shapes, but rather of the fact that specific pairs of items in these sets shared shape features along dimensions that were at the same time critical to distinguish among objects, something that did not exist in single dimension sets.

A subsequent experiment corroborated this interpretation and showed that ELM's deficit was not one of perceptual encoding, but rather that it concerned the stored representations of object shapes or access to these memory representations (Arguin et al., 1996a, experiment 5). This experiment assessed perceptual encoding while placing minimal demands on memory for visual shapes and used exactly the same stimulus sets as the previous shape–location task. Thus, on every trial, a single target shape was shown at the centre of a computer screen for 1s. Then, following a blank delay of 1s, the four stimuli of the set the target belonged to were displayed simultaneously for an unlimited duration, each at a randomly determined corner of the computer screen. ELM's task was simply to point to the shape that matched the previously displayed target. In this experiment, ELM made a single error out of 240 trials with shapes from conjunction sets (0.004% errors) but made an error on 8.8% of trials with single dimension sets, a difference that was highly significant. This result demonstrated the greater difficulty of perceptual discriminations among items from single dimension sets and confirmed that the deficit exhibited by ELM with conjunction sets in the previous shape–location experiment concerned the integration of features defining the shapes of objects held in memory.

The observations obtained from ELM with synthetic shapes confirmed inferences based on his initial testing, namely that his deficit affected the structural description stage of visual processing. Most importantly, however, they also provided a detailed description of this deficit, which can be characterised as one affecting the integration of features defining the shapes of objects held in memory. That such a deficit led to CSVA affecting particularly biological objects is congruent with the notions discussed in the preceding sections, according to which this disorder is largely a function of the greater visual similarity between biological objects than between man-made objects. The concept of visual similarity that was highlighted by the results of Arguin et al. (1996a), however, dissociates from one referring to overall discriminability among shapes, as defined by the Euclidian distance separating items in a perceptual shape space (e.g. Garner, 1974; Shepard, 1991). Rather, these results indicated that the relevant definition of visual similarity is according to whether or not items share features with one another on critical dimensions that determine their shapes.

Interaction of shape by semantic processing

Even for the theories discussed above that implicate visual similarity as a key element in explaining visual recognition impairments specific to biological objects, some additional factor seems to be required for a complete account of this type of disorder. In the context of visual object recognition, the concept of similarity requires a reference group that specifies what a particular target object is similar to. The relevant reference group for all of the visual similarity theories of CSVA discussed above is always made of objects that belong to the same semantic category as the target. The reasons why this is so are not always transparent, however. One clear and explicit statement that has been made in this regard is by Riddoch, Humphreys, and their collaborators (Forde et al., 1997; Humphreys et al., 1988, 1995; Riddoch & Humphreys, 1987b). For these authors, the reason why the reference group against which visual similarity is assessed is made of objects of the same category is because the visual object recognition system operates in cascade. This implies the occurrence of interactive effects of factors that tap separate processing stages, notably those concerned with the visual shape of an object (i.e. perceptual encoding and structural descriptions) and those concerned with its meaning (i.e. semantic memory). Thus, what their theory predicts is that increased visual similarity between objects will cause some uncertainty on the representation of the target at the stages processing its shape. This uncertainty will then be transmitted to semantic memory, where it will be magnified if the items that are visually similar to the target are also semantically related to it. In other words, the prediction is for an overadditive interaction of visual similarity and semantic proximity, such that the effect of visual similarity will be exclusive to, or much greater for, semantically related objects than for items that belong to separate semantic categories. A complementary hypothesis suggested by Arguin et al. (1996a) that could contribute to the interaction of visual similarity with semantic proximity is that of feedback from semantic memory to structural descriptions, which could help separate the shape representations of visually similar items if they are semantically very distinct from one another.

Decisive tests of the predicted interaction between visual similarity and semantic proximity are extremely difficult to produce if the visual stimuli used make explicit reference to real-world objects. Attempts of partial tests of this interaction in CSVA patients have been made by Forde et al. (1997), as described earlier, as well as by Arguin et al. (1996a, experiment 6). The visual and semantic properties of real-world objects are inextricably tied, however, and the contribution of each of these factors can hardly be separated completely. One way to escape this difficulty is to devise a new kind of paradigm where the links existing between the visual shape of an object and its meaning become entirely under the control of the experimenter. Such a paradigm, affording a full exploration of the visual similarity by semantic relatedness interaction, has been developed by Dixon et al. (1997), who have applied it to ELM.

As described at the beginning of this chapter, it is widely assumed, both in cognitive psychology and neuropsychology, that the links within the object recognition system between the visual shape and the name of an object are not direct, but rather that they are mediated by semantic memory. In terms of the present purpose, this means that if one were able to force the links between the shape of an item and an arbitrary name it has been assigned to pass through a particular conceptual representation in semantic memory, it would become possible experimentally to manipulate the semantic value of a visually presented item independently of its shape. This is what Dixon et al. (1997) attempted.

The initial paradigm that was developed was one where the subject was asked to learn arbitrary associations between a visual shape and a particular sound that referred to an object that was recognisable by the subject. In the test phase, a visual shape was then shown by itself and the subject was asked to provide its name. In their experiment 2, for instance, Dixon et al. (1997) asked ELM to learn to associate the sounds of a leaf-blower, of water being poured into a glass, of a motorcycle, and of a telephone ringing, with each of a set of four distinct shapes. In the test phase, ELM was then required to indicate whether the single shape presented was the "leaf-blower", the "water", the "motorcycle", or the "telephone". The sounds used corresponded either to semantically related or unrelated objects and the shape sets tested within this paradigm were single dimension or conjunction sets, such as defined by Arguin et al. (1996a; see earlier).[4] In support of the assumptions underlying the paradigm, results showed that the semantic relatedness of the objects referred to by the sounds indeed had an effect on ELM's performance, with semantically related sounds leading to poorer performance. Most importantly, the results showed an interaction between the effects of shape set (single dimension versus conjunction) and semantic relatedness (close versus distant). Thus, the effect of semantic relatedness was absent with single-dimension shape sets, which also produced smaller error rates than conjunction shape sets. The effect of semantic relatedness was very large with conjunction sets, however. For instance, in the second half of the experiment, ELM made 41.14% errors with the semantically related conjunction sets, but no error at all with semantically unrelated conjunction sets. A subsequent experiment (experiment 3) using the same paradigm showed that the

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[4] As in Arguin et al. (1996a), shapes from single-dimension sets were less discriminable from one another than those from conjunction sets. The results, described later, again support a definition of visual similarity in terms of shared shape features among objects rather than Euclidian distance between objects in shape space.

shape-by-semantics interaction was independent of whether the sounds used referred to biological or man-made objects. This indicated that what controlled ELM's visual identification performance was indeed the combined factors of visual similarity among shapes (in terms of whether or not they shared critical features) and semantic relatedness, not the biological versus non-biological distinction *per se*.

However, the most remarkable finding from ELM came from an extension of the shape–sound paradigm described earlier, where object sounds were simply replaced by auditory object names (Dixon et al., 1997, experiment 4). Thus, ELM was first asked to learn specific shape–name associations and was then tested with shapes shown individually, to which he had to respond with their assigned names. Strikingly, this rather elementary procedure was sufficient to attach the meaning referred to by the name to a simple visual shape that had no prior association with this semantic content (this was revealed to be true not only in ELM, but also in neurologically intact controls; Dixon et al., 1997, experiment 6). Indeed, the results from the shape–name task replicated those from the shape–sound paradigm. Those observations were then extended in another experiment using the shape–name paradigm with single-dimension and conjunction shape sets along with name sets that varied parametrically in their semantic relatedness (Dixon et al., 1997, experiment 5). The results showed no effect whatsoever of semantic relatedness on ELM's performance with single-dimension sets (error rates with these stimuli averaged between 10% and 20%). Thus, the correlation between his error rates with single-dimension sets and the degree of semantic proximity among the names used was .06. In sharp contrast, the error rates with conjunction sets increased very markedly (from about 0% to 66%) and linearly with an increased semantic relatedness between the names. The correlation between error rates with conjunction sets and semantic relatedness was 0.81. Again, this effect of semantic relatedness with conjunction sets of shapes was independent of the biological versus man-made distinction.

The above experiments show unambiguously that ELM's visual object recognition performance is controlled jointly by the existence of shared shape features among objects that must be distinguished and by their semantic relatedness. Specifically, the stimulus context that is disproportionately problematic for ELM in a visual recognition task is one where the processing of conjunctions of shape features is required to uniquely identify items that are closely related in terms of their assigned semantic content. Given the differing properties of biological and man-made objects discussed previously, these observations from ELM can account for the category selectivity of the patient's visual agnosia without the need to assume fundamental differences in the way biological and non-biological categories are represented. These results also fit with the fact that, within the realm of man-made objects, ELM has (as have several other CSVA cases) major difficulties in the visual recognition of musical instruments and makes of cars; categories that also comprise objects that are highly similar in shape. The joint effect of visual similarity and semantic proximity also applies to ELM's profound difficulties with face recognition. In an extension of the shape–name paradigm, Dixon et al. (1998) asked ELM to learn unique and arbitrary associations between visually presented (unknown) faces and famous people's names that referred to semantically related or unrelated individuals. ELM's performance was profoundly impaired (up to 60% errors) with sets of visually similar faces that were assigned semantically related names. By contrast, his performance was at a level indistinguishable from that of matched controls if visually similar faces were assigned semantically unrelated names or if visually very distinct faces received the names of related famous persons.

Legitimate questions still remain however, relative to the implications that can be derived from the studies of patient ELM. One such question is whether the notion of shared shape features, as well as its interactive effect with semantic proximity, remains relevant with respect to other individuals. Indeed, although it was possible to document the properties of ELM's visual recognition impairment in great detail, the possibility remains that the functional architecture that was documented is quite unusual, for reasons related to particular features of either the patient's brain damage or his development. Another question pertains to the properties of a visual recognition system that are required to account for the joint effects of shared shape features and semantic relatedness. In principle, the structure of the visual recognition system argued for by Humphreys, Riddoch, and their collaborators (Forde et al., 1997; Humphreys et al., 1988, 1995; Riddoch & Humphreys, 1987b) appears relevant. However, the currently existing implementation of this model (Humphreys et al., 1995) is based on local object representations in the shape domain, i.e. the shape of an object is represented "holistically" by a single processing unit in the model. This organisation appears incompatible with shared shape features as the index of visual similarity to which ELM was particularly sensitive, as opposed to Euclidian distance between object representations in shape space. Indeed, the effect of shared shape features such as demonstrated by ELM (and in other instances as well, see later) suggests that visual shapes are represented as distributed collections of discrete features and that a particular integration operation is required to distinguish reliably between items that have critical shape features in common (see Arguin et al., 1996a; for an elaborated discussion of this issue). We may therefore ask whether it is possible to achieve the interactive effects of semantic relatedness and visual similarity in a model where the shape of an object is explicitly defined over a set of distributed, discrete features. The next two sections will address these issues in turn.

GENERALISATION OF IMPLICATIONS FROM ELM

Sensitivity to shared critical features among shapes that must be discriminated, as well as to the semantic relatedness of labels assigned to them, are not exclusive to ELM. Other instances of such effects have been observed. Possibly the most relevant case is that of patient IL, who showed CSVA due to brain damage produced by herpes simplex encephalitis (Arguin et al., 1996b). Following his recovery, IL complained of major memory problems—initially claiming no recollection of his past life, a problem that partially resolved afterwards—as well as prosopagnosia and visual object agnosia. On matched sets of line drawings of biological and man-made objects from the Snodgrass and Vanderwart (1980) set, he made 65% errors on biological items but only 20% with man-made items. Like most other CSVA cases, IL's visual perceptual encoding was intact but he showed major difficulties in accessing stored structural descriptions of biological objects, both from vision (46% errors with animals and 48% errors with fruit and vegetables in the object decision task) and from verbal questions (45% errors on two-alternative forced-choice questions). His performance in these tasks was substantially better with man-made objects (28% errors on object decisions; 10% on verbal questions). His semantic memory appeared relatively spared and his performance on verbal questions probing non-sensory knowledge did not vary as a function of whether they concerned biological or non-biological objects (15% errors in both conditions).

IL was tested on the shape–name learning paradigm where semantically related or unrelated names were assigned arbitrarily to items from single dimension or conjunction shape sets that were made of four stimuli each. Although IL performed very poorly in this task (overall error rate of 57%), his results nevertheless revealed an interactive effect of shape set by semantic relatedness of the same form as that previously observed in ELM. Thus, IL's performance was unaffected by semantic relatedness with single dimension shape sets (59% and 53% errors with semantically related and unrelated labels, respectively). However, his performance with conjunction shape sets was much worse if items were assigned semantically related (74% errors) rather than unrelated (43% errors) labels. These results constitute a replication of the previous key findings from ELM (Arguin et al., 1996a; Dixon et al., 1997). Additionally, they also support the account of CSVA based on the joint effects of shared shape features and semantic proximity, as well as its implications for the organisation of the visual object recognition system.

Another category of brain-damaged patients with whom the shape–name learning paradigm has been applied with interesting results are those with dementia of the Alzheimer's type (DAT; Dixon, & Arguin, 1999). Such patients frequently suffer difficulties in visual object recognition and a number of reports suggest that these difficulties are greater with biological than man-made objects (Daum, Riesch, Sartori & Birbaumer, 1996; Mazzoni et al., 1991; Silveri, Daniele, Giustolisi, & Gainotti, 1991). Dixon and Arguin (1999) tested DAT patients using the shape–name learning paradigm where each of a set of three shapes was paired arbitrarily with a particular object name. One class of shape sets was made of items that shared multiple features among themselves so that the processing of conjunctions of shape features was required for unique identification (conjunction sets). The other class of stimulus sets was made of items that could be distinguished from all the others by the processing of a single shape feature (single-feature sets). Name sets were semantically related or not and were made of terms referring either to biological or man-made objects. Over their two experiments, Dixon and Arguin (1999) found no effect of the biological/non-biological distinction in the terms used but main effects of shape set and of semantic relatedness of the names. Thus, error rates were about doubled with conjunction relative to single-feature shape sets as well as with semantically related relative to unrelated names. Irrespective of the implications these results might have regarding particular clinical features of DAT or the apparent category specificity of visual recognition deficits in this disorder, the observations of Dixon and Arguin (1999) clearly show that shared-shape features and semantic relatedness are major determinants of performance in individuals other than ELM.

Shared-shape features also affect perceptual encoding in neurologically intact individuals. Arguin and Saumier (2000) had normal observers perform visual searches for predetermined target shapes that differed from distractors either by a single feature or by a conjunction of features. For instance, in the single-feature condition the target could be defined relative to distractors by its unique value on the shape dimensions of elongation or curvature. In the conjunction condition the target had the same value as some distractors on the dimension of elongation and the same value as other distractors on the dimension of curvature, thus requiring the processing of combinations of shape features for accurate target detection. Results showed markedly slower search rates in the conjunction than the single-feature condition and separate control experiments demonstrated that the discriminability of the targets and distractors was effectively equated across these conditions. Thus, the slower search rates in the conjunction condition are specifically attributable to the fact that processing combinations of shape features was essential in this condition whereas this was not required in the single-feature condition. These observations demonstrate that sensitivity to shared-shape features in visual performance extends beyond ELM and that it is a property of the intact visual perceptual encoding system.

MODELLING THE INTERACTION BETWEEN SHARED-SHAPE FEATURES AND SEMANTIC RELATEDNESS

The theory of visual object recognition proposed by Humphreys, Riddoch, and their collaborators (Forde et al., 1997; Humphreys et al., 1988, 1995; Riddoch & Humphreys, 1987b) appears capable of producing the interactive effects of visual similarity and of semantic proximity that are required to account for category-specific effects in CSVA. The implemented version of this theory, however, is based on local representations of object shapes, a property that contradicts the findings cited above from ELM, IL, DAT patients, and neurologically intact observers. These argue instead for distributed representations of object shapes that are made of collections of discrete features that must be integrated when objects share shape features with one another.

To account for the observations made in patient ELM, Dixon et al. (1997; see also Dixon et al., 1998, Dixon & Arguin, 1999) have proposed an alternative model where shape representations are based on collections of discrete features. This model was largely inspired from the ALCOVE model, which was initially proposed as an account of various visual categorisation data (Kruschke, 1992). The system of Dixon et al. (1997) encodes visual shapes through a series of input nodes, each coding a feature value defining the item on a particular shape dimension. Activation from these input nodes is then transferred to a hidden layer that represents exemplars as points in a multidimensional psychological space. This psychological space acts as a long-term memory that has the dual responsibility of coding stored properties about objects on both visual and semantic dimensions. The hidden exemplar layer connects to output units responsible for the production of responses identifying a particular target shape applied on the input units. Two key features largely determine the operation of the model. One is the assumption of a limited pool of attentional resources in the connections between input and hidden units (Nosofsky, 1986). Thus, if a particular condition requires the processing of multiple shape dimensions for correct discriminations among objects (as in conjunction shape sets), the overall attention pool is divided across these dimensions. Less attention is therefore available for each relevant stimulus dimension than if correct performance can be supported by the processing of a single stimulus dimension. In that case, all of the attentional resources can be directed to that dimension and none is allocated to the irrelevant dimensions. The other major feature of the model is that activation within the hidden layer is not an all-or-none matter, but rather is a graded function of the similarity between the exemplars stored in this long-term memory and the stimulus presented on the input layer. Specifically, it was assumed that activation in the hidden layer falls off exponentially as the similarity between the stimulus values coded at input and in the hidden layer decrease. The rate of this fall-off of activation is a function of a specificity parameter that controls the selectivity of units in the hidden layer. The simulations conducted by Dixon et al. (1997) using this model replicated the effect of shared-shape features shown by ELM in the shape location task as well as the interactive effects of shared-shape features and semantic relatedness in the shape–name task (the latter result was also found in IL [Arguin et al., 1996b] as discussed earlier). These observations were produced by decreasing the selectivity of units in the hidden layer, without affecting the connections between input and hidden exemplar units or the attention weights that modulate their function. Crucial to the production of the above results is the fact that the hidden exemplar layer codes both visual and semantic properties of known objects. Impairment of this level of processing by reducing the selectivity of units therefore renders the network overly sensitive to both visual similarity and semantic proximity. As these two factors affect the same level of processing, they will also interact with one another (Sternberg, 1969, 1998), thus replicating the results of ELM in the shape–name task. However the very feature of Dixon et al.'s (1997) model that appears crucial in simulating the findings from ELM is also problematic. Indeed, the long-term memory store that is assumed to be impaired in ELM codes both visual and semantic knowledge of objects. This predicts an impairment affecting stored visual as well as semantic object properties. This assumption is contradicted by the dissociation exhibited by ELM (as well as by other CSVA patients) between impaired access to stored structural descriptions but intact semantic knowledge.

A more recent series of simulations (Rzempoluck, Bub, & Arguin, 1998) have been conducted using a trainable cascade connectionist network with an architecture very similar to that of Dixon et al. (1997). The major innovation, however, was that two (instead of just one) hidden layers were used, one representing stored knowledge of object shape and the other semantic properties. This architecture is highly consistent with that described at the beginning of this chapter and appears entirely compatible with the occurrence of dissociations between the structural descriptions and semantic memory stages. Simulations of ELM's and IL's performance in the shape–name task were conducted on this model following selective damage to the connections between the input nodes, which code feature values on specific shape dimensions, and the first hidden layer, which corresponds to the structural descriptions stage. Results showed the same interactive effects of shared-shape features and of semantic relatedness as exhibited by ELM and IL, even while the model codes these two factors at separate processing stages.

CONCLUSIONS

This chapter has reviewed the literature on visual object recognition impairments attributable to a presemantic deficit and that are specific to biological object categories. Several authors concur that such impairments are not a function of a categorically organised visual object recognition system but rather that they reflect the greater visual similarity of objects within biological than man-made categories. In particular, it has often been assumed that the greater within-category similarity for biological objects renders them more difficult to dissociate from each other and, therefore, more susceptible to the effects of brain damage. The studies of patient ELM that are reviewed above have provided the first controlled experimental demonstration that visual similarity and semantic proximity do indeed jointly determine visual object recognition performance in category-specific visual agnosia. These investigations have implications that extend beyond the particular case of ELM. Notably, results have argued for distributed representations of object shapes that are made of collections of discrete features. Support for this assumption has been found in patient IL (who is another case suffering from CSVA), DAT patients, and neurologically intact observers. Finally, we report computational models that are capable of replicating the interactive effects of visual similarity and semantic proximity documented in patients ELM and IL while implementing a distributed code for shape representation.

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