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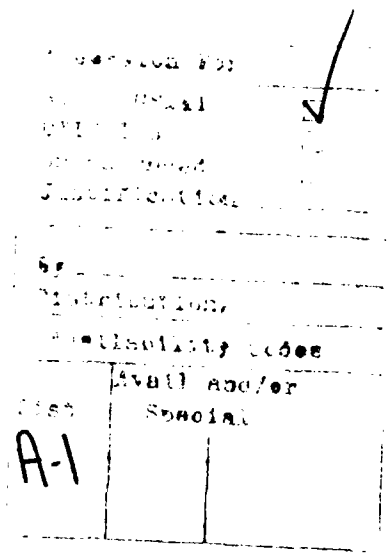
The functional architecture of visual object recognition

Final Report

Martha J. Farah, Principal Investigator

July 1991



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Final Report

ONR Grant N00014-89-J-3016
"The functional architecture of visual object recognition"

Martha J. Farah, Principal Investigator

The goal of this grant was to constrain our theories of visual object recognition, including face and printed word recognition, using evidence from brain-damaged and normal subjects. This research is continuing with a current ONR grant. In this final report I will summarize the progress we made during the period of the initial grant. This summary will be organized according to the general issues addressed by the research.

Object representation

One of the most basic questions we can ask about object recognition is: How is object appearance represented for purposes of recognition?

By observing the patterns of association and dissociation among abilities after brain damage, one can infer the architecture of those abilities in the normal brain. In the case of object recognition, the different forms of agnosia can provide clues to the representations underlying normal object recognition (Farah, 1990). For example, the pair-wise dissociability of the recognition of faces, common objects and printed words suggests that there is more than one system of representation needed to recognize these different types of stimuli.

At first glance, we might conclude that there are three different types of recognition ability, for faces, common objects and

words. However, although each is pairwise dissociable from the others, not all three-way patterns of deficit and sparing occur. In a review of 99 published cases of agnosia, the observed patterns of co-occurrence implicated two underlying types of visual object representation (Farah, 1991). One type is necessary for words, somewhat useful for objects, and not at all useful for faces; the other type is necessary for faces, somewhat useful for objects, and not at all useful for words.

We hypothesized that the first form of object representation, essential for reading, involves the rapid encoding of multiple visual shape units, and that the second form of object recognition, essential for face recognition, involves the encoding of complex shapes holistically, that is, without part decomposition. Further research was then conducted to test this hypothesis.

We identified a patient with an impairment in reading, and demonstrated that he was impaired at the rapid encoding of multiple shapes, even when the shapes were not orthographic (Farah & Wallace, 1991). We recently replicated this finding with three additional patients (unpublished data).

We began testing our hypothesis about face recognition with normal subjects. Tanaka and Farah (submitted) have demonstrated that parts are relatively less accessible, in the visual memory of faces than in the visual memories of three different types of contrasting stimuli: scrambled faces, inverted faces, and houses. We also (Tanaka & Farah, in press) explored an alternative hypothesis concerning what is "special" about face recognition: Diamond and Carey's "second order relational properties" hypothesis, which had

never been directly tested, was tested and disconfirmed. In on-going research, we are testing our hypothesis about face recognition using new experimental paradigms, and also with patients who have face recognition impairments.

The literature on single unit recordings and ablations in animals is another source of evidence on object representation. Plaut and Farah (1990) reviewed this literature and offered interpretations of the physiological data in a computational vision framework. One of the issues about object representation in cognitive science that has been most controversial is whether object shape is coded in an object-centered or viewer-centered frame of reference. We pointed out that there is abundant neurophysiological evidence for object-centered representation of shape in the primate visual system.

A more direct approach to the question of object-centered representations was taken by us in a reaction-time study with normal subjects (McMullen & Farah, in press). We showed that symmetrical objects do appear to be recognized using object-centered representations, in that the time to recognize them does not vary as a function of their orientation. In contrast, asymmetrical objects do require some orientation-normalizing process, as evidenced by increased latencies to name misoriented stimuli, consistent with the use of viewer-centered representations. This suggests that object-centered representations of shape do exist, but that they code spatial relations among one dimension only, as proposed by Tarr and Pinker.

Category-specific impairments

One of the most striking neuropsychological phenomena, from the point of view of theories of object recognition, is the finding that some patients have impairments in recognizing living things. We were initially skeptical, and believed that the apparently selective deficit in the recognition of living things could be explained by the confounding of such factors as complexity, familiarity, etc. with the living/nonliving distinction. However, Farah, McMullen and Meyer (1991) studied the recognition ability of two patients with impaired recognition of living things, and attempted to model their performance, statisically, using ratings of the complexity, familiarity, specificity, confusability, and name frequency of a large number of drawings of living and nonliving things. Although some of these other factors were significant predictors of patient performance, they did not account for the living/nonliving dissociation. Even with all other factors, and interactions, in the model, the living/nonliving factor accounted for a highly significant amount of the variance in patient performance. In sum, the living/nonliving dissociation appears not to be a simple artifact of greater recognition difficulty for living things.

It is still possible that the living/nonliving dissociation reflects some feature of objects that is highly correlated with the living/nonliving distinction, but is not "aliveness" per se. In a PDP modelling project with Jay McClelland (Farah & McClelland, in press), we found that we could account for the basic phenomena oberved in these patients using a memory architecture which distinguished between *visual* and *functional* information, rather than information

about living and nonliving things. We verified experimentally that living things are defined primarily by their visual attributes, whereas knowledge of nonliving things is more evenly distributed among the different types of sensorimotor information in memory. Damage to the visual information units in the model led to a selective impairment for living things, and damaging the functional information units led to a selective impairment for nonliving things (a syndrome that is rarer but has also been observed).

Visual recognition and conscious awareness

In recent years neuropsychologists have documented a number of syndromes in which perception and awareness of perception appear to be dissociated. These syndromes are of potentially great interest for what they might tell us about the neural bases of consciousness.

One of these syndromes is "extinction," in which parietal-damaged patients are unable to recognize the contralesional stimulus when two stimuli are presented simultaneously, one on each side of space. Even though patients with extinction cannot identify the contralesional stimulus, they have been found to be able to make same/different judgements comparing that stimulus to the ipsilesional stimulus! This has led to the suggestion that such patients do perceive the contralesional stimulus, but that this percept cannot reach conscious awareness. We (Farah, Monheit & Wallace, in press) have argued that this is not the correct interpretation. In experiments with normal subjects and with extinction patients, we have shown that same/different matching simply demands less

We (Farah, Soso & Dasheiff, in press) were fortunate to encounter a very high-functioning, educated young woman who was a candidate for unilateral occipital lobe resection for treatment of epilepsy. We were able to estimate the visual angle of her mental images before and after surgery, thus using her as her own control. We found that the size of her biggest image was reduced after surgery. Furthermore, by measuring maximal image size in the vertical and horizontal dimensions separately, we found that only the horizontal dimension of her imagery field was reduced. These results paralleled the change in size of her visual field, and provide strong evidence for the use of occipital visual representations during imagery.

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