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Concept neurons: A proposed developmental study

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A neurophysiological experiment is proposed to determine the existence of visual object concept neurons. The basic technique is to deprive newborn animals of all visual experience with the exception of a small number of objects exposed one at a time in a Ganzfeld. Such a demonstration would be important in extending the range of validity of the principle of specific neuron encoding.

This paper offers a potentially important idea for a neurophysiological experiment which I am in no position to perform, so I am passing it along to anyone who is interested. The idea is a possibly practical way to determine the existence of *grandmother cells*—single neurons that encode object concepts (and eventually other concepts as well).

Despite all the disclaimers, what made Hubel and Wiesel's (1962) findings so exciting was the extension of Johannes Müller's (1838) doctrine of specific nerve energies to a higher level. One cannot, logically, believe that Hubel and Wiesel's papers are telling us something significant about visual coding and simultaneously assert that it is the temporal pattern of neural firing that matters or the spatial (holographic, distributed, etc.) pattern of firing frequencies over a large number of neurons in the brain. Hubel and Wiesel's research is exciting because it suggests that it is the rapid firing of a very small number of neurons that represents a line of a particular orientation at a particular location, etc.—*which* neurons are firing rapidly, not *how* they are firing or some complex firing-rate function defined over all neurons in the brain or visual cortex. Of course, there is some encoding redundancy (more than one neuron responds vigorously to any given stimulus), and each neuron has a modest generalization gradient of response to suboptimal stimuli. These are factors of some importance, but they should not obscure the basic principle of specific neuron coding of the basic line (and angle?) constituents of visual patterns. Certainly one should pay no attention to the pseudosophisticates who always darkly hint that things "can't be as simple as that" without saying why not and without offering any specific alternatives. They pretend to know something every knowledgeable person should know about why simple specific-neuron encoding cannot work. The listener often does not know, but is embarrassed to reveal his "ignorance" (often even to himself). The truth is that specific-neuron coding will work for higher leve[...] and concept representation in the nervous [...] there is lots of evidence that the nervous system [...] work this way and no good evidence that it wo[...] other way. There is lots more evidence to acqu[...] lots more thinking to do about exactly how th[...] uses specific element encoding in perception, m[...] cognition, response, etc. Furthermore, no one [...] deny the usefulness of any scientist developing [...] alternative theories of coding—distributed, holo[...] or whatever. But specific-neuron coding is the do[...] and most plausible theory of coding in the [...] system and we should not be ashamed to a[...] believe in it, if we do.

The current frontier in the long drawn-out c[...] of mental phenomena by the theory of specific [...] encoding is learned concepts. Is "grandmother" [...] in one's mind by means of a "granny" cell? E[...] I have disposed of supposedly "logical" objec[...] the theory of learned concept neurons and sp[...] plausible selectional mechanism by which an un[...] (free) neuron can come to be specified (bound) [...] for a conjunction of constituent neurons (Wi[...] 1969, Note 1). The basic principle is that each [...] neuron be weakly connected to about 10^4 oth[...] neurons [approximately equal to the number of [...] neurons in the cortex (see Pakkenberg, 1966)] [...] ever one wishes to chunk some set of attr[...] specify a new chunk neuron, one inhibits th[...] bound neurons and primes the free neurons so [...] maximally activated neuron will be one of [...] neurons. The free neuron which will be most [...] activated is the one which receives the greatest [...] to the convergent (direct or indirect) connecti[...] previously bound feature neurons repres[...] attribute constituents, of the chunk. This [...] chunk neuron representing that set of co[...] Since this neuron is the one most strongly [...] following the activation of the constituent ne[...] the familiar (though unproved) neural con[...] ditioning mechanism, the synapses linking [...] stituent neurons to the chunk neuron are st[...]

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ssume that strengthening one set of synaptic neuron represses the other synapses. This the new chunk neuron from interfering it cannot come to stand for any other chunk nstituents) in the future (at least not until and previously facilitated synapses become weak disuse or whatever).

We have only specified a mechanism for achieving the conjunctive aspect of concepts. There edly, also a disjunctive aspect (the sets of activating the cat concept are totally dif- the sets of auditory cues, etc.) The dis- pect can be handled, too, but it is beyond the this brief paper.

point of this note is to suggest one way to other objection to specific-neuron encoding that there is no (systematic) evidence for ons. Of course, Thompson, Mayers, Robertson, on (1970) found single neurons encoding ncepts such as two, five, six, or seven, but bers might be special, innately coded con- representative of concepts in general. Further- my knowledge, no attempt has been made to these findings. Then there is the famous hand" cell discovered by Gross, Bender, and nda (1969); virtually no one expects to this sort of finding because the odds that any on will represent a monkey hand must be very specific-neuron encoding principle holds for presentation. This is the essence of the prob- so many possible learned concepts, how could ysiologist have much hope of finding what particular cell represents, assuming that uron encoding is true?

swer may be to use the restricted rearing mployed so successfully in recent years to in- the beautiful interaction of genetic and learned on at the featural levels of the visual system. A nimal could be reared in an environment completely dark except at times when the restrained, wearing a collar, and the visual Ganzfeld except for a single object selected small set of objects (on the order of 4 to mably, such visual experience would be salient enough to promote perceptual learn- al concepts, but if not, the objects could be lly associated with subsequent presentation) of food, water, shock, etc.

ptual learning proceeds by specification of a on to represent each object concept, then probing of inferotemporal cortex, associa- etc. with microelectrodes should find cells nd primarily to presentation of one of the much less to any other familiar or unfamiliar course, since the visual experience of these s so restricted compared to, for example, esthetic, motor, and auditory experience, to find fewer areas of the brain (or fewer neurons in any area) that can be driven at all by visual stimuli. However, this should be a relatively minor problem compared to trying to figure out what combination of visual features drives a cell optimally. It is this latter problem that restricted rearing ought to make enormously easier.

Rather than using just any small set of objects, it might be best at first to use sets defined so that objects differ on two, three, or four dimensions with two, three, or four values each. Then it could be definitely demonstrated that a single cell responded in a super-additive manner to a conjunction of features compared to its response to objects posessing only a subset of the features defining the concept.

Since an object concept neuron would almost surely be activated by presentation of the appropriate object at any distance and angular orientation, there is probably no need to control this carefully, but one could if necessary. Eventually it would be interesting to determine the necessary and sufficient conditions for integrating different views (e.g., front and back) of an object into a common concept. To do this, it might be necessary to use tachistoscopic presentation of one view for a variable period of time, followed by a different view after a variable interstimulus interval.

Looking even farther down the road, one might present objects performing characteristic movements (moving up, expanding, vibrating back and forth, etc.) and see if one could find action concepts. Two objects might be presented at the same time in characteristic relations (one above the other, touching, etc.) to see if single neurons encode relational concepts. Finally, one set of objects could always be presented together and never with any of the members of another set and vice versa. Possibly there would be context neurons that responded vigorously to any object in one set, but not to any object in the other set.

Usually research on the development of some psychological competence or neural system follows research on this competence or system in adults. In the case of concept neurons, there may be good reason to reverse this order.

After writing this brief paper I learned that Michalski, Kossut, and Zernicki (1975) and Zernicki and Michalski (1974) had used visual deprivation in young kittens with selective exposure to certain objects to study the effects on units in Areas 17, 18, and 19 of visual cortex. Their experiments gave little support to the hypothesis that these visual cortical areas contain object concept neurons. However, based on receptive field studies in normal animals, there is no good reason to believe these early visual cortical areas are encoding complex, learned object concepts. Rather, these areas appear to encode the simpler, largely innately specified, line and angle constituents of object concepts. Zernicki and Michalski looked in the wrong place. Their experiment also differed in a number of other ways from that proposed here.

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ERRATUM

Newman, S. E., and Frith, U. Encoding specificity vs. associative continuity. *Bulletin of the Psychonomic Society*, 1977, 10, 73-75. Page 75, column 1, line 26 should read: "This may have occurred since (1) in the Thomson and Tulving experiment the instructions prior to the recall test were shorter for the no-cue than for the strong-cue group and (2) strong-cue subjects, in both their experiment and ours, faced with a list of words that had not previously occurred in the experiment, . . ."