Representation within the brain

Clearly, cultural representational systems such as language and pictures have "interpretive systems" that depend on the brains of their users, but here the Palmer "ordered triple" runs into problems. For the physical "representing world" provided by our culture must itself be represented in the user's brain before the brain's "interpreting system" can have access to it, as also must be the "represented world." But does not this necessity lead inevitably to the much ridiculed "homunculus" paradox – an infinite regress of minds within the mind with each interpretive system needing representations of the representation it interprets? In the past this criticism has usually been reserved for the idea of depictive or "analogue" representations within the brain (e.g., Pylyshyn 1973, 1981).

To make sense, a depictive representation within the brain could only represent by Shepard's "secondary isomorphism," implemented in terms of assemblies of neurons in which connectivity and synaptic strength rather than physical structure provide the medium of representation. There are candidates for such a "secondary" depictive medium in the numerous modular regions of the visual cortex that contain arrays of columns of neurons that topographically map the visual field. Some of these have been shown by brain-imaging studies to map spatially both visual percepts and mental images (Kosslyn 1994).

However, for such neural topographic maps to qualify as the medium of representational systems (Palmer 1978) it is necessary to posit other neural processes which can scan, manipulate and interpret spatial information in ways that correspond to "design thinking." There is strong evidence that the brain provides an array of such "covert" interpretive processes to extract information from such neural representations. Moreover, this evidence seems to strengthen rather than weaken the forbidden (and ridiculed) homunculus metaphor of an inner designer, a brain within the brain, complete with an "inner pencil" to draw imagined objects (Kosslyn et al. 1988), an "inner eye" to inspect them (Kosslyn et al. 1979), "inner hands" to move and rotate them (Shepard et al. 1982) and an "inner voice" and "inner ear" (Baddeley and Lewis 1981) as the brain talks to itself.

Two classes of information, necessary for design thought within the brain, have been described as "descriptive." The first class consists of hypothetical long-term memory structures that are used both for visual recognition and mental imagery. Theories of "recognition by parts" based on contour segmentation (Hoffman and Richards 1984) or on an analysis into three-dimensional shapes (Biederman 1987) are partly descriptive. More recent evidence suggests that the brain also stores and uses individual views of objects or object prototypes which, though normalized for size and position, are nearer to depiction in the descriptive–depictive continuum (Tarr and Pinker 1989). The format of long-term remembered information about objects is important to the theory of sketch function. However, it is not clear that such information structures deserve to be classed as "representations" of the sort that can be used for design thought, for the "interpretive process" of visual recognition is an automatic retrieval and comparison process that is largely outside conscious control. However, two aspects of recognition theory are important for the understanding of designers' sketches. The first is the evidence that brains are well adapted for recognizing objects when incomplete, poorly illuminated or partly obscured stimuli are presented to the eyes. An incomplete contour fragment or object part can be used as a look-up key to long-term memory (Hoffman and Richards 1984). The second is the evidence that the long-term stored structures used for recognition are the same structures used for generating mental images (reviewed Kosslyn 1994). Recognition and imagery also appear to share resources such as those used for size scaling, mental rotation, and template matching.

The other descriptive system, language, is surely used when we reason covertly to ourselves. Experimental evidence suggests that when we reason to ourselves about categories, concepts, and propositions, we use the same components of working memory that we use when we generate or understand speech (Baddeley 1986). The existence of separate storage and processing modules as posited by the Baddeley and Hitch model for the manipulation of linguistic and visuo-spatial knowledge has recently been confirmed by brain-imaging studies (Jonides and Smith 1997).

Less well understood is the supervisory "central executive," a complex of processing resources that has been linked to planning, attention, and conscious awareness (Baddeley 1993). Perhaps a future understanding of this component will allow us to claim that there is a part of the brain, not a mind within the mind, but a cognitive recorder and controller, that can explain how it is possible for non-homunculus neural processes to create the illusion of an "inner designer" that is able to monitor, control, and report its own private information processes.[4]

Uncertainty and the need for type translation

"To invent is to choose," said Poincaré in a much quoted essay (Poincaré 1915). Design problem solving must negotiate many degrees of uncertainty. It can be thought of as the problem of choosing an acceptable route through a mental tree or bush where the trunk and branches are vague or abstract and necessarily descriptive, to some of the multiple "leaves" representing depictively concrete thought. Thus the decision tree of visual thought differs from the "problem space" of Newell and Simon (1972) in that it contains both descriptive propositions (branches) and depictive images (leaves?) with a constant need to translate between the two modes of representation. But it is a magic tree, for the act of exploration causes new branches to grow and old ones to wither.

Max Black (1937), one of the forefathers of fuzzy logic, distinguished three types of indeterminacy, all of which can be applied to sketches. *Generality* occurs when an idea that may be descriptively precise specifies a category with many exemplars. *Ambiguity* occurs when a choice has not yet been made between two or more alternatives. *Vagueness* (Black's word for a fuzzy limiting boundary) occurs whenever there is a need to specify structure, form or colour approximately for later refinement.

When we wish to represent these forms of uncertainty mentally to ourselves, we find that both description and depiction are interdependent. A visual description is useful and memorable in proportion to the number of depictive images it allows us to generate. Poetry and literature move us by their power to evoke visual memories. Since the time of Plato, it has been known that verbal ideas are easier to remember if they are associated with a