All the proposed functions were ways of supporting components of working memory and there are good grounds for supposing that working memory is a resource which places limits on the brain's capacity for design thinking (Logie and Gilhooly 1998). It is therefore an obvious candidate for sketch support. Unfortunately, "working memory" – the temporary storage and processing resources used by the designing brain for manipulating internal representations of imagined objects – is itself composed of multiple modules. More is known about separate modules for processing language, visuo-spatial information and for directing attention than is known about how these components interact. Although linguistic and visual memory systems are often treated independently, in design thinking they are interdependent and the brain must possess translation mechanisms between the two that perhaps need cultural support (Paivio 1986). Here I argue that sketch function two (Support for Perceptual Memory Retrieval) and sketch function three (Support for Superimposed Imagery) are both slave functions of function one (Translation of Representational Type). To explain this I will use a metaphor based on chemistry – "cognitive translation catalysis."

The need for such "catalysis" is due to maladaptations in the brain that we have inherited from our Ice Age ancestors.

The Brains We Inherit from Palaeolithic Humans

Why is it that, despite enormous recognition memories, we find it relatively difficult to visualize and mentally manipulate absent objects or events? Why is the limited capacity of our working memory so poorly adapted to a lifestyle and culture that places heavy demands on foresight and planning? In order to design better sketching systems we need to understand not only how our brains work, but also *why* they work the way they do. Some of the answers may be found in evolutionary psychology.

"Is it not reasonable to anticipate that our understanding of the human mind would be aided greatly by knowing the purpose for which it was designed," remarked the biologist George Williams in an influential book on evolution (Williams 1966). By "designed" Williams knew that every biologist would understand that he was referring to the adaptive advantages produced by Darwinian natural selection. Our brains evolved the way they have by the accumulation, by survival and successful reproduction, of small, inherited variations in our nervous systems. In our evolutionary past every genetic part of our brains must have improved the competitive survival rate and fecundity of those individuals who possessed them. Evolution by natural selection is not really design at all, although it looks like design. For such evolution to occur at least two conditions are necessary. The first is long periods of time. The random mutations (copying errors) and recombination of our genes that are necessary to accumulate a significant number of advantageous inherited changes to our nervous systems need thousands of generations of parents and offspring. Evolution usually occurs very gradually in tiny successive changes since large, single-step changes to our genetic make-up are nearly always disadvantageous. The second condition is consistent selective pressure. There must be something about our lifestyle and environment that causes certain genetic variations in our brains to survive and be reproduced more than other variations. Changes to our brains that are caused by learning from the environment or transmitted by culture are not inherited and cannot cause our brains to evolve. But the selective pressure must last long enough to allow enough genetic variation to occur. If the environment and lifestyle change too quickly, then evolution cannot keep pace with the selective pressure, and an organism's anatomy and instinctive behaviour can be maladapted to its present condition. The genetic make-up of an organism can only be understood by considering its evolutionary past. Biologists refer to this as the evolutionary "time-lag" (Dawkins 1982). Because of this time-lag, there may be parts of a species' anatomy and instinctive behaviour that are no longer adaptive. Their existence may even be puzzling to biologists if they are ignorant about the exact conditions surrounding an organism's evolutionary past. Many species survive with a certain amount of such "time-lag." This is normal, but with our species the time-lag is dramatic. The 8000–10,000 years since our ancestors emerged from the last Ice Age, planted the first crops and invented writing, is less than one five-hundredth of the time that it took our brains to evolve from the ancestors we share with our nearest relative, the chimpanzee. The post-Ice Age invention of agriculture, cities, and writing has occurred in too short a time to allow a significant evolution of the brain. And the Industrial Revolution with its concomitant separation of design from manufacture is less than the flicker of an eyelid in biological time. Yet the last hundred years have witnessed a hundredfold growth of scientific knowledge (Ziman 1976, p. 56) and a demographic explosion that have caused massive changes to our environment and lifestyle. There is no known mechanism by which our genes can have adapted to cars, city planning or computers. Thus, our brains evolved for solving problems that were quite different from those that our culture now imposes on it. Although there probably have been small genetic changes to our nervous systems in the last 10,000 years, archaeologists consider our upper palaeolithic ancestors, who lived in Europe and Asia during the Würm glaciation between 35,000 to 10,000 years ago, to be anatomically modern humans. They possessed a brain that was the same size and shape as ours. It is to their lifestyle rather than ours that our brains are adapted. Consider what can happen to our brain–body systems when we are driving in heavy traffic. Responding to stress, our brains cause adrenalin or noradrenalin, the hormones of aggression and fear, to be circulated in our bodies. This process in turn causes microglobules of fat to be squirted into our blood. This adaptation increased the survival chances of our ancestors, providing much needed energy to our muscles for attacking a mammoth or fleeing a lion. However, for the modern motorist sitting in a car, the fat piles up in the heart and arteries, causing one of the fastest growing causes of mortality in Western culture.

A time-lag, less obvious perhaps and poorly understood, also exists in the neural resources we are endowed with for thinking about and imagining future objects and events. It took 2½ million years for the brains of the first tool-making species of the genus Homo (*Homo habilis*) to increase in size from an average 600 cu. cm. to the 1350 cu. cm. we possess today (Lewin 1993). In most groups of related mammal species, the ratio of brain size to body surface is approximately constant. If this ratio is used as an "index of encephalization" (Bauchet and Stephan 1969), then the index for most primates (including our nearest relative) is 11.3 times that of an insectivore. However, the index for modern humans breaks the primate rule and is 2½ times greater. The greatly expanded neocortex, with its much larger prefrontal