communication of a kind that implies the use of language in the upper palaeolithic humans (de Beaune 1995). Most archaeologists agree that, by then, humans had developed spoken language, although how sophisticated it was and how it was used can only be guessed. As Pinker argues persuasively, the language instinct probably evolved slowly and gradually by the Darwinian process of tiny successive steps, from vocal sounds with simple meanings to the conceptual abstraction and the rich, recursive phrase structure of today's languages.[1]

Experts are still debating the adaptive advantages that language conferred on our ancestors. The obvious first function of language is communication. Language must have coevolved with the instinct for social cooperation in groups, providing the advantages of collaborative hunting of large game and the ability to communicate information about food sources for scavenging or gathering. Another theory suggests that language replaced the grooming that is used for social bonding in other apes. According to Dunbar (1996), neocortex size, group size and language coevolved, as language replaced grooming in larger groups as a means of cementing friendships to ensure future cooperation and to learn how other individuals were likely to react to a given behaviour. In support of his theory, Dunbar has shown that there is a linear correlation in primates between cortical ratio (the ratio of the size of the neocortex to the size of the rest of the brain) and group size. The human cortical ratio is 50% larger than the chimpanzee's. Using this correlation he was able to predict that human group sizes should be 150 (on average). His predicted data agree well with what is, in fact, found in modern hunter-gathering societies but is, of course, greatly exceeded in technological cultures. Is this another example of time-lagged brains?

Not every expert agrees that communication was the primary advantage driving language evolution. Jerison (1991) has argued forcefully that the primary reason for language evolution was not communication, but conceptual thought. Language is needed for sequential reasoning about possible outcomes of a planned action. Jerison argues that inner reflection and the power to elicit private imagery, not outer communication, was the facility that drove language evolution. Communication was a useful consequence of this facility. It seems to me that the debate about which came first, communication or conceptual thought, is vain. Selection would surely have worked simultaneously on both communicating and reasoning skills, making them evolve in tandem. The key point is that verbal thought can be verbally shared with others, but that when we think with mental imagery there is no comparable innate mechanism for sharing our imagery.

Archaeologists have been divided over whether the increase in the size of the hominid brain was driven by the needs of hunting and tool-making or by the advantages of language (Leakey 1994; Lewin 1993). Recently, it has been suggested these three activities may have shared neural resources and a common origin. Calvin (1993) points out that activities such as the skilful striking of a flint or the accurate throwing of a spear occur too quickly to be controlled by neural feedback and correction. The brain needs sequence buffers in which the complex sequence of muscle commands can be prepared and mentally tested before such actions can be executed smoothly. Calvin suggests that neural circuits that evolved for planning skilled movements could have been adapted later by evolution for planning the sequences of phonemes and words necessary for speech. "An elaborated version of such a sequencer may constitute a Darwin machine that spins scenarios, evolves sentences and facilitates insight by off-line simulation" (Calvin 1993). Earlier, Corballis (1991) proposed that one reason why 95% of right-handed persons have both handedness and language controlled by the left side of the cortex is that both language and manual dexterity use shared mechanisms of non-spatial "praxis." Studies of early hominid stone tools show that they were made by people with lateralized brains like ours (Leakey and Lewin 1992). Interestingly, it has been shown recently with brain imaging techniques that Broca's area, long thought to be specialized only for language production, is also active during manual control (Blackmore 1999).

The theme that mental capacity often depends on "borrowing" and adapting neural resources that evolved for a different function is central to the theory of sketch function. In the Baddeley and Hitch model, a specialized component of working memory, the "phonological loop" is used for the temporary storage of words and symbols during language production and comprehension. It is also used for counting, mental arithmetic, and problem solving. Baddeley and his colleagues have distinguished two subcomponents, a passive acoustic store and an articulatory rehearsal process. The traces of remembered words continually fade in the acoustic store and must be revived by the rehearsal process. The capacity of this store is only five to seven items. When we reason to ourselves about categories and concepts we use an "inner voice" and an "inner ear" (Baddeley and Lewis 1981). Such a sound-based memory system may be well adapted to the quick response needs of a hunter-gathering lifestyle: "Is anyone missing?", "Watch out, the bison is going to charge," etc. When fast responses are needed, a low-capacity, fast-fading word store might even help the brain to prepare for the next message. However, such a short-lived memory store is hardly well adapted to the sequential reasoning needs of a reflective, symbol-processing culture. The very fact that linguistic working memory is based on the sounds of words rather than their symbolic meanings is evidence for an evolutionary time-lag. There is no innate working memory store specific to reading and writing. Of course, we can and do supplement such a poor facility for conceptual reasoning with visual working memory (e.g., Hayes 1973). However, as I argue in the next section, visual working memory is also time-lagged and, besides, designers need their visual working memories for purposes other than symbol processing.

The Visualizing Instinct

We have inherited from our primate ancestors one of the most sophisticated visual systems in the animal kingdom. The task of analyzing the confusing light patterns presented to our retinas is parcelled out to about 34 separate specialized regions in the cortex of our brains (Zeki 1993). Many of these contain maps of either the image on the retina or of the visual field. It has long been known that our brains must supplement the information provided by our eyes in order to reconstruct the visual scene of meaningful three-dimensional objects that we experience when we say we "see." As the reindeer runs away, the image on the hunter's retina gets smaller in direct proportion to the distance. But the Stone-Age hunter sees his game is staying the same size and accurately perceives its changing distance and speed. His