and the Structure of Behaviour (Miller, Galanter and Pribham 1960) and the *Ghost in the Machine* (Koestler 1967). More recently the notion of a single executive has tended to become replaced by the idea of 'agents'. These mental agents look after our thinking just as the human agents we use in everyday life look after our affairs. We employ an estate agent, for example, to find people interested in buying our house, or perhaps to find houses we might like to buy. They thus work purposefully towards a relatively simple goal. A butler is perhaps the ultimate personal agent who operates by really understanding the wishes and aspirations of the master and who almost certainly then subcontracts work to a series of more specialised agents. If the cognitive psychologists prove to be right about executives and agents then we may expect to discover much more about the way we design. If we could understand the forces and operations which are responsible for switching our attention from one part of a problem to another or allowing us to reorganise our perceptions in new ways, we should be well on the way to understanding the design process.

The cognitive theorists' approach to thinking is also attractive to those who seek to understand the design process because it draws many parallels between thought and perception. Both primary and secondary processes are postulated, the primary thought process being a multiple activity like parallel processing in computers. These crudely formed thoughts are similar to the preattentive processes in vision or hearing being only drawn to our conscious attention if selected for detailed and deliberate elaboration by the secondary processes. It is in the secondary processes where all the real work is done. These processes have to be acquired and developed, and are dependent upon what is already memorised and the way material has been organised in primary processing. The cognitive theories thus lay great emphasis upon the way we organise perceived information and store it. Failure to recall is seen as analogous to a failure to notice something in a visual scene. Attention in perception and thought is seen as responsible for directing our thoughts and thus crucial to problem-solving. This theme will be taken up again in a rather less theoretical and more practical way when we consider methods of stimulating creativity and improving problem-solving skills in design.

However, there remain many problems with what has now become known as the cognitive science approach to thought. The actual performance of artificial intelligence remains so far behind that of human thought in so many ways that there must be doubts as to whether the two can ever be comparable. The cognitive science approach is

strongest when dealing with well-ordered problem-solving situations rather than the ill-defined 'wicked' problems which are so characteristic of design. The 'computational theory of mind' underpins the whole of the cognitive science by assuming that thought can ultimately be reduced to a computation process. Now for a such a process to be possible there must be information on which to work. For that information to be capable of being processed it must conform to some rules akin to those of languages which determine the range of symbols and the allowed relationships. The cognitive scientist Jerry Fodor (1975) summarises this problem for us:

> If our psychological theories commit us to a language of thought, we had better take the commitment seriously and find out what the language of thought is like.
>
> (Fodor 1975)

In a book rather neatly entitled *Sketches of Thought*, Vinod Goel (1995) begins to confront these problems. He analyses the sketches produced by designers and finds it impossible to define a language sufficiently rigorously for the demands of the theory. In a later chapter we shall ourselves try to understand the central role of drawing and sketching in design. It is interesting, however, now to find that cognitive scientists are increasingly interested in design for the very reason that explaining it tests their theories to, and possibly beyond, their limits.

Types of thinking

At the beginning of this chapter we saw many types of thinking and concluded that reasoning and imagining were probably the most important to designers. Reasoning is considered purposive and directed towards a particular conclusion. This category is usually held to include logic, problem-solving and concept formation. When 'imagining', on the other hand, the individual is said to draw from his or her own experience, combining material in a relatively unstructured and perhaps aimless way. Artistic and creative thought as well as daydreaming are normally considered imaginative.

This kind of simplistic taxonomy is perhaps as misleading as it is apparently helpful. If reasoning and imagining were truly independent categories of thought, one should not be able to speak sensibly of 'creative problem-solving' or a 'logical artistic development', which are both quite meaningful concepts. Many kinds of problems, even in such apparently logical disciplines as engineering,