Introduction to Cognitive Science

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1 CRUM

Thagard [17, p. 10] expresses the main assumption or central hypothesis of cognitive science as follows:

> Thinking can best be understood in terms of representational structures in the mind and computational procedures that operate on those structures.

This assumption is known as the *computational-representational understanding of the mind*, or *CRUM* for short, and also as the *computational conception* of the mind. (The diagram shown in Fig. 1 elaborates CRUM. This diagram is based on Searle's characterisation of cognitive science in *The Rediscovery of the Mind* (1992), pp. 197–198, and also on Thagard's in *Mind* (1996), pp. 10–12.)

Cognitive scientists disagree about the nature of the computational processes that take place in the intermediate level and also about the form that the mental representations take. The main approaches are based on logic, rules, concepts, analogies, images and connections. (See Thagard, *Mind* [17], chapters 2–7, for more information about these.) These approaches are summarised in Table 1, which is based on Table 8.1 on p. 129 of Thagard's *Mind*.

CRUM should not be confused with a particular theory of mental representations and processes, such as that based on rules. CRUM is more general and, currently, accepted by all cognitive scientists. Several philosophers of science distinguish between *paradigms* [6] or *research programmes* [7] or *research traditions* [8] and particular *theories* that fall within a specific research programme. Paradigms are more general and harder to overthrow than particular theories. Fetzer is one of those who distinguishes between cognitive science, as a discipline, and CRUM, as the current dominant paradigm within cognitive science [4, pp. xvi–xvii]:

> In the case of an emerging new discipline such as cognitive science, there is an almost irresistible temptation to identify the discipline itself (as a field of inquiry) with one of the theories that inspired it (such as the computational conception ...). This, however, is a mistake. The field of inquiry (or "domain") stands to specific theories as questions stand to possible answers. The computational conception should properly be viewed as a research program in cognitive science, where "research programs" are answers that continue to attract followers.

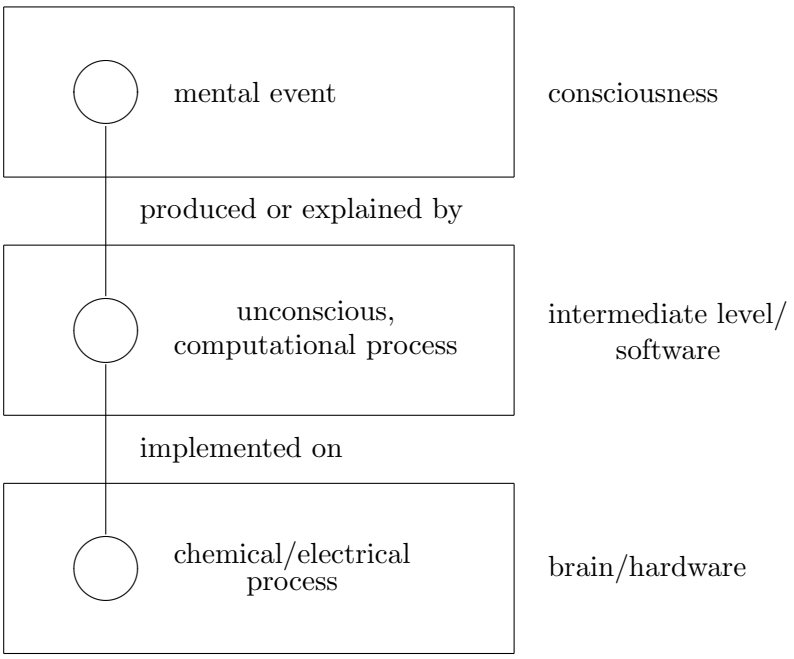

Figure 1: CRUM.

	representation	problem solving	learning
logic	propositions operators predicates quantifiers	deduction plausibility	generalisation abduction
rules	if–then	search forward chaining backward chaining	chunking generalisation abduction
concepts	frames with slots schemas scripts	matching inheritance spreading activation	abstraction from examples conceptual combination
analogies	target and source causal relations	retrieval matching adaptation	storage schema formation
images	visual, motor, etc.	matching manipulating	imaginary practice
connections	units and links	parallel constraint satisfaction	backpropagation weight adjustment

Table 1: Summary of theories within CRUM.

CRUM is the guiding assumption of an important research tradition. The idea of the discipline of cognitive science is far less interesting. Disciplines as such are not very important. The things that are important are problems and the theories put forward to solve them. Popper makes this point as follows [10, p. 5]:

> There are no subject matters; no branches of learning—or, rather, of inquiry: there are only problems, and the urge to solve them. A science such as botany or chemistry (or say, physical chemistry, or electrochemistry) is, I contend, merely an administrative unit. University administrators have a difficult job anyway, and it is a great convenience to them to work on the assumption that there are some named subjects, with chairs attached to them to be filled by the experts in these subjects. It has been said that the subjects are also a convenience to the student. I do not agree: even serious students are misled by the myth of the subject. And I should be reluctant to call anything that misleads a person a convenience to that person.

In his book *In Search of a Better World* (1992), p. 69, Popper writes:

> A so-called scientific subject is merely a conglomerate of problems and tentative solutions, demarcated in an artificial way. What really exists are problems, and scientific traditions.

Popper used to give the following advice to his students [1, p. 252]:

- You must have a problem, *not* a topic.
- Do not *try* to be original. Find a problem that excites you. Work on it and take what you get.
- You must *want* to communicate to your reader; you must be clear, never use big words or anything needlessly complicated. ...
- It is immoral to be pretentious, or to try to impress the reader or listener with your knowledge. For you are ignorant. Although we may differ in the little things we know, in our infinite ignorance we are all equal.
- Do not be attached to your ideas. You must expose yourself, put yourself to risk. Do not be cautious in your ideas. Ideas are not scarce: there are more where they came from. Let your ideas come forth: *any* idea is better than no idea. But once the idea is stated, you must try *not* to defend it, not to *believe* it, but to criticize it and to learn from discovering its defects. Ideas are only conjectures. What is important is not the defense of any particular conjecture but the growth of knowledge.
- So be scrupulous in admitting your mistakes: you cannot learn from them if you never admit that you make them.

Unfortunately, many people think that you cannot study a subject unless you have a definition of what that discipline is. They try to answer the following sorts of question:

- What is philosophy?
- What is cognitive science?
- What is artificial intelligence?
- What is computer science?
- What is physics?
- What is archaeology?

To convince you that asking and answering such questions is a pointless waste of time I will first present a number of definitions of 'cognitive science'.

2 Some Definitions of Cognitive Science

The first definition of *cognitive science* is from the Oxford *Dictionary of Computing* [12, p. 83]:

> **cognitive science** A multidisciplinary research field involving artificial intelligence, cognitive psychology, linguistics, neuroscience, and philosophy. The goal is to understand the phenomena of thinking and the relationship between brain and mind. Progress depends upon work on computer simulations, perception, language, mental states, and consciousness.

The next definition of *cognitive science* is from Thagard's book *Mind* [17, p. ix]:

> Cognitive science is the interdisciplinary study of mind and intelligence, embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology. Its intellectual origins are in the mid-1950s when researchers in several fields began to develop theories of mind based on complex representations and computational procedures. Its organizational origins are in the mid-1970s when the Cognitive Science Society was formed and the journal *Cognitive Science* began.

The next definition is from *The Macmillan Dictionary of Psychology* [16, p. 83]:

> **cognitive science.** In theory, any discipline that studies cognition scientifically; in practice, any discipline that purports to do so, including sociology, social anthropology, linguistics, psychology, and aspects of philosophy and AI: the expression has come into being mainly in order to allow workers who are not scientists to claim that they are. Cognitive scientists rarely pay much attention to the nervous system. *Contrast* NEUROSCIENCE—the two are almost mutually exclusive in that cognitive science deals with the brain's software, neuroscience with its hardware.

The next definition is from *The Penguin Dictionary of Psychology* [13, p. 130]:

> **cognitive science** A newly coined name for the cluster of disciplines that studies the human mind. The term refers to an amalgamation; it is an umbrella term which includes a host of once disparate approaches such as cognitive psychology, epistemology, linguistics, computer sciences, artificial intelligence, mathematics and neuropsychology.

Gardner in *The Mind's New Science* defines *cognitive science* as follows [5, p. 6]:

> I define cognitive science as a contemporary, empirically based effort to answer long-standing epistemological questions—particularly those concerned with the nature of knowledge, its components, its sources, its development, and its deployment. Though the term *cognitive science* is sometimes extended to include all forms of knowledge—animate as well as inanimate, human as well as nonhuman—I apply the term chiefly to efforts to explain human knowledge. I am interested in whether questions that intrigued our philosophical ancestors can be decisively answered, instructively reformulated, or permanently scuttled. Today cognitive science holds the key to whether they can be.

The next definition is from Trask's *A Student's Dictionary of Language and Linguistics* [18, p. 45]:

> **cognitive science** The scientific study of the human mind, including such aspects as perception, intuition, acquisition of knowledge, reasoning and speaking. Cognitive science is an interdisciplinary field combining contributions from linguistics, psychology, philosophy, computer science and artificial intelligence.

The next definition is from the *Collins Dictionary of Artificial Intelligence* [15, p. 56]:

> **cognitive science,** *n.* the field that studies the mechanics of human intelligence. Cognitive science also involves the investigation of the processes involved in producing intelligence in a given situation.

Allan Collins in the first issue of the journal *Cognitive Science* defines it as follows:[1]

> Cognitive science is defined principally by the set of problems it addresses and the set of tools it uses. The most immediate problem areas are representation of knowledge, language understanding, image understanding, question answering, inference, learning, problem solving, and planning. . . . The tools of cognitive science consist of a set of analysis techniques and a set of theoretical formalisms. The analysis techniques include such things

[1] This is quoted from Dreyfus's *What Computers* Still *Can't Do* [3, pp. 309–310]. The ellipsis is in the quotation in Dreyfus's book.

> as protocol analysis, discourse analysis, and a variety of experimental techniques developed by cognitive psychologists in recent years. The theoretical formalisms include such notions as means-ends analysis, discrimination nets, semantic nets, goal-oriented languages, production systems, ATN grammars, frames, etc.

Ask yourselves the following questions about these definitions:

- Are they informative?
- Are they helpful?
- What do they leave out?
- Are they distorted? (And if so, how?)
- What is the point or purpose of such definitions?
- Can such a complex, multifarious and diverse field as cognitive science be completely characterised in a short formula?
- Did any of these definitions help you to understand what cognitive scientists do or did you find my characterisation of CRUM more informative?

3 Essentialism

Why do people try to define disciplines? The theory that academic disciplines like AI, cognitive science, physics, biology, psychology, archaeology, etc., exist and are distinguishable by subject matters that they investigate is a residue from a philosophical position known as *essentialism* which—amongst other things—insists that an academic subject had to proceed from a definition of its own subject matter. Popper makes this point as follows [9, pp. 66–67]:

> The belief that there is such a thing as physics, or biology, or archaeology, and that these 'studies' or 'disciplines' are distinguishable by the subject matter which they investigate, appears to me to be a residue from the time when one believed that a theory had to proceed from a definition of its own subject matter. But subject matter, or kinds of things, do not, I hold, constitute a basis for distinguishing disciplines. Disciplines are distinguished partly for historical reasons and reasons of administrative convenience (such as the organization of teaching and of appointments), and partly because the theories which we construct to solve our problems have a tendency to grow into unified systems. But all this classification and distinction is a comparatively unimportant and superficial affair. *We are not students of some subject matter but students of problems.* And problems may cut right across the borders of any subject matter or discipline.

The idea that in order to develop a theory you have first to define its subject matter sometimes leads to ludicrous definitions, such as the following definition of 'linguistics' (*Ampersand: The Elsevier Science Linguistics Newsletter*, # 2 (September 1998), p. 1):

> Definitions of academic fields can be contentious, but it is probably not too controversial to say that linguistics as a field of academic research can be regarded as comprising a theoretical core and a periphery of interdisciplinary and applied areas.

A common problem encountered by people who take disciplines seriously is that sooner or later they come to realise that in orer to solve many problems you require ideas and theories belonging to several disciplines. This leads to many pseudo-problems about inter-, cross- or multi-disciplinary research. William Bechtel, for example, thinks that cognitive science is not a discipline, but a cross-disciplinary enterprise ("Cognitive Science" (1995), p. 128):

> While there are a few common institutions that seek to unify cognitive science (e.g., departments, journals, and societies), the problems investigated and the methods of investigation often are limited to a single contributing discipline. Thus, it is more appropriate to view cognitive science as a cross-disciplinary enterprise than as itself a new discipline.

Gardner, however, thinks that one day cognitive science will come into being [5, pp. 6–7]:

> At present most cognitive scientists are drawn from the ranks of specific disciplines—in particular, philosophy, psychology, artificial intelligence, linguistics, anthropology, and neuroscience ... . The hope is that some day the boundaries between these disciplines may become attenuated or perhaps disappear altogether, yielding a single, unified cognitive science.

Does it matter whether cognitive science is a discipline or a cross-disciplinary enterprise? What is important is CRUM as that has increased our understanding of how the human mind works. Those who argue that cognitive science involves several disciplines are not helped in their cause by the fact that they cannot even agree about what disciplines contribute to it. (See Table 2.)

	A	B	C	D	E	F
linguistics	×	×	×	×	×	×
artificial intelligence	×	×	×	×	×	×
philosophy	×	×	×		×	×
epistemology				×		
psychology		×	×		×	×
cognitive psychology	×			×		
neuropsychology				×		
neuroscience	×	×			×	
anthropology		×			×	
social anthropology			×			
sociology			×			
computer science						×
computer sciences				×		
mathematics				×		

A The Oxford *Dictionary of Computing* [12, p. 83].
B Thagard, *Mind* [17, p. ix].
C *The Macmillan Dictionary of Psychology* [16, p. 83].
D *The Penguin Dictionary of Psychology* [13, p. 130].
E Gardner, *The Mind's New Science* [5, p. 7].
F Trask, *A Student's Dictionary of Language and Linguistics* [18, p. 45].

Table 2: Component disciplines of cognitive science.

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