COGNITIVE SCIENCE AS A MULTICULTURAL SCIENTIFIC COMMUNITY, AND SOME IMPLICATIONS FOR THE DESIGN OF COGNITIVE SCIENCE EDUCATION PROGRAMS

Nils Dahlbäck
Department of Computer and Information Science
Linköping University
S-581 83 Linköping, Sweden
nilda@ida.liu.se

Abstract

An alternative view of cognitive science as neither one unified cognitive science, nor just a multidisciplinary field of a number of sciences (psychology, AI, linguistics, philosophy, neuroscience etc.) is presented. It is argued that cognitive science is best described as a matrix of two dimensions, a content or domain dimension (e.g., language, problem solving etc, and subsets of these) and a methods dimension, comprising of three basic approaches to research; empirical, formal, and model building. The latter are seen not only as methods per se, but rather as scientific 'cultures'; carriers of differing explicit and implicit views of what constitutes 'good research'.

The paper presents the 'three cultures' view of cognitive science, and describes how this has influenced the general design of the undergraduate program in cognitive science at Linköping University.

1 Introduction

Ever since its early days, the views of what cognitive science is, but even more, what it should grow into, has shifted (Gardner, 1987). The major difference seems to be between those who want the field to grow into a unified discipline or science (e.g. Roger Schank, one of the founding fathers of the Cognitive Science Society), and others (e.g. Gardner) who rather see it as best remaining as a multi-disciplinary field of study[1].

For most practitioners in the field, working in established research areas, this issue is probably of less interest or importance, just as most of today's AI researchers do not seem to spend to much time or interest on whether the visions of the proponents of so-called 'strong AI (Searle, 1980) will ever become true or not. It seems to me that there are basically two kinds of academics that have a direct interest in these issues. First, the theoretician or philosopher of the field, and second, the educator. Both have an interest in finding a coherent view of the field. But there is an important difference between these two endeavors, which in some sense parallels the difference between science and engineering. For the former, it is more important to getting the answer right than having the answer now. For the latter, the reverse is true; something has to be done now and hence provisional answers, positions or solutions must suffice, even if they lack the thorough theoretical and empirical foundation required for scientific theories. The present paper tries to address the issue of how to describe a coherent view of cognitive science, from the educators of necessity provisional perspective.

The reason that I believe that the question of how to describe the field of cognitive science is important for educators is the following: For all undergraduate programs, but especially so for interdisciplinary ones like Cognitive Science, it is important to base them on a coherent view of the subject area or areas under study. For a large field like ours, with many different sub-areas and different perspectives, we need criteria for deciding what to include and what to exclude from the curriculum. If not, there is a risk that the students will be presented with a rather haphazard collection of courses that reflect the research interest of the present faculty more than any-

[1] It is interesting to note in this context that the Swedish translation used to describe Lund University's Cognitive Science is 'Kognitionsforskning' (which would literary translate into something like *research on cognition*), and not 'Kognitionsvetenskap' (*science of cognition*), which is used by other Swedish cognitive science nodes.

thing else. Ten years ago, when the computational theory of mind was the dominant one within cognitive science, the task of finding one such coherent perspective was probably an easier task than it is today.

I will illustrate my arguments with examples from the design and development of the Linköping Cognitive Science undergraduate and Master's curricula. In our work on this, we have striven to use results and insights from different sub-fields of cognitive science, so in a limited sense, we have recursively used cognitive science research to understand what cognitive science is and how to design an undergraduate program in cognitive science.

2 Defining Cognitive Science

Cognitive science is often described in textbooks and elsewhere as 'the science of mind'(Stillings et al., 1987). This is often described as comprising of five or six disciplines or sciences (philosophy, psychology, AI, linguistics, neuroscience and anthropology). The standard introductory presentation often also points to the representational or information processing view of mind as central to cognitive science; "The mind is seen as a complex system that receives, stores, transforms, retrieves and transmits information"(McTear, 1988), p 13. An ongoing discussion in the field, ever since its start, has been whether it will develop into one unified science of cognition, as envisaged by e.g. Pylyshyn (1984, p xi), or if it will or should remain an interdisciplinary meeting ground for the different sciences of mind mentioned above, and possibly others, as e.g. Gardner argues. My claim here, however, is that we need not have to choose between only these two alternatives.

One problem with the traditional taxonomy of the subfields of cognitive science is that it conflates methods and topic areas. All the different cognitive sciences not only have a core study object, but also a methodological tradition associated with it. Linguists study language, but so do psychologists and others. Psychology has a strong empirical tradition, but also anthropologists, neurologists and linguists run empirical studies, while some psychologists write computer programs, just like workers in AI. But there are AI researchers who never write any programs, but instead develop mathematical and logical models, as do philosophers and linguists – and the circle is closed.

Another problem with the 'standard view', is that the selection of what to include as relevant seems somewhat arbitrary. The listing in the journal *Cognitive Science* of which disciplines belong to the field has changed over the years (Schunn, Crowley, & Okada, 1998), and (Simon & Kaplan, 1989) have pointed out that other disciplines than those of tradition associated with the field, e.g. economics, could belong there.

I believe, however, that there are alternatives to the 'standard' views. One such viewpoint, originally presented in (Dahlbäck, 1991), is that Cognitive Science is better described by a matrix of two dimensions; a *content* or *domain* dimension (language, memory, problem solving, etc, and subsets of these), and a *methods* dimension, comprising of three basic approaches to research; *empirical*, *formal*, and *model building*, and subsets of these. The first defines the study object of cognitive science; the second describes the major different scientific traditions in the field.

In this paper I will concentrate on the methodological dimension, but first a few words on the content dimension. An approximate definition of the subject field of cognitive science could be something like "the information processes of natural or artificial agents' interaction with the physical and social environment". It is admittedly loose, but delimits cognitive processes (information processing, in its widest sense) from emotive, volitional and other aspects. Furthermore it sets an 'upper' boundary towards sociology and similar 'macro' social sciences, and a 'lower' boundary towards the genetic information processes. The definition is purposely vague in the view of the relationship between cognitive and neurological aspects, as well as of the relationship between how much of the individual's cognitive processes are taking place 'in the head' or 'in the world'. It includes those aspects of e.g. neurological processes that have a direct bearing on the organism-environment interaction, but leaves it open where this border actually is. Likewise it includes tool-based external support of these processes, but leaves it open where this border actually is.

Not also that a possible feature of the definition above, is that its emphasis is less on what is actually *in* the head of the agent, but more on the organism-environment interaction, where implicitly the internal representations are seen as subservient on this. It is therefore, if the pun be permitted, an attempt to put the rationalistic heritage in cognitive science on its head.

3 Cognitive Science as three methodological 'cultures'

The reason that I find the methods dimension important is that it, in a sense, is *not* about research methods, and definitely not about methods only. Associated with these methods are different views on science and theory, not the least the view of what constitutes ‘good scientific work’ etc., like which of the two criteria of internal coherence and correspondence between theoretical concepts and empirical data is the most important one. They are therefore in important respects different scientific ’cultures’, or different ways of ‘doing science’, rather than just different methodological traditions.

The empirical-formal distinction has a long tradition, and can perhaps most clearly be illustrated by work on logic and thinking by logicians and psychologists. The work of the psychologists is descriptive and empirically based, and the correspondence between theory and data is the major evaluative criterion. The work of the logicians is on the other hand prescriptive, there is a limited interest in the empirical base, and coherence or correctness from a formal point of view is the major evaluative criterion. The important point is of course that there is no ’right’ and ’wrong’ here, but while the study object in some sense is the same, the scientific traditions are different.

The third category here, the constructive or model building (sometimes called design science, or science of the artificial(Simon, 1996b)) is best exemplified with AI within cognitive science, but seems in many respects to share features with much of engineering science in general. It shares with the formal tradition a concern with the suitability of formalisms, but the emphasis is rather on ’external’ criteria, such as a particular formalism’s suitability for a particular task, rather than its soundness, completeness, and other similar evaluative criteria. It shares with the empirical tradition the concern with and interest in studying some kind of ’external reality’, but in contrast with traditional empirical science, the objects studied are not given by nature but constructed by man.

There are of course also important different traditions also *within* the different major classes. These are often more discussed, e.g. the difference between quantitative and qualitative empirical methods, for and against logic-based approaches to AI etc.

There is one interesting but often overlooked difference between classical empirical research and design oriented research, which perhaps is most clearly seen in applied areas of cognitive science, e.g. HCI, and which concerns the relationship between theory and empirical data. In traditional empirical science there is a tight connection between the theory and the empirical data, which means that the latter will have a more or less clear-cut bearing on the theory. In design oriented research, on the other hand, the connection between the theories and the evaluation of the designed artefact is much looser. Consequently, the consequences of the results of the empirical evaluation for the theories that inspired the design will not be as clear-cut in this case. Let me illustrate this point with examples from two different fields, cinema and clinical psychology.

Imagine a director creating a movie, which, he claims, is inspired by Jung’s theories of the collective unconsciousness. It is then a rather pointless review, which concentrates on whether this movie is really a true interpretation of what Jung actually meant. First, because it is obvious that being inspired by something is not the same as deriving hypotheses from a theory into predictions that can be tested in an empirical study. Second, because the value of the movie is primarily not in how good a reflection of Jung’s theories it is, but how good it is as a piece of art.

Behavior therapy is another illustration of this. One can of course debate whether behaviorism is an accurate and adequate theory of human behavior, and likewise one can certainly debate whether e.g. Wolpe (Wolpe, 1958) made correct interpretations of the basic theories of learning he based his work on, and whether he made reasonable additional assumptions in the derivation of a therapeutic approach from these basic assumptions, but that is of course not the most important issue from a clinical point of view. The important issue is instead whether the therapy works. And conversely, a study showing that it works cannot of necessity be seen as a validation of standard behaviorist theories. The coupling between the theory and the evaluation is too loose for this.

Getting back to the basic issue of the three scientific cultures, I do not want to claim that the present formulation of these three scientific traditions is all that clear cut and well developed as it stands today. But even in its present form, it has a useful heuristic value for the design of a cognitive science curriculum. The argument here is that one of the central characteristics of cognitive science, and which perhaps makes it unique among established scientific fields of study, is that it encompasses all three of these methodological traditions/cultures. And that this need to be reflected in the cognitive science curriculum, since any competent cognitive scientist in academia or industry, needs some basic knowledge in all three areas. This in contrast with many educational programs in cognitive science which, in taking a leap from the computational theory of mind, has a course or two in programming as a requirement for the exam, but no such requirements for e.g. experimental methods and design, or logic.

4 Why ‘methods as culture’ is important

There are a number of reasons for our emphasis on the plurality of methods. From an educator’s point of view, one of the most obvious is of course that it is a valuable knowledge in itself. Another reason for this is that this kind of knowledge has a longer life (theories change, methods remain), and furthermore that it is easier to teach yourself about theoretical developments than about programming, experimental design, or formal logic.

But the most important reason for our emphasis on this, is that ’hands-on’ knowledge of the methods used in a piece of research will give the student a deeper understanding of the results obtained and the conclusions possible to draw from it. You cannot really understand a Cookery book if you cannot cook, you will never really understand what sailing is like by only reading about it, etc, and I take this to be true for all knowledge areas involving an important amount of practice. Which programming, experimental design etc seems to belong to too. In this it is very similar to the process of acquiring cultural knowledge. And we know, of course, not the least from work in one sub-field of cognitive science, i.e. anthropology, that there is no substitute for living in a culture if you want to understand it from within, rather than from without (*pace* Simon’s travel theorem[2]).

Another reason for our emphasis on this is the accumulating cognitive science research on what characterizes successful scientific work, e.g. (Dunbar, 1995), (Schunn et al., 1998). Two of these factors are multidisciplinarity, and within this diversity some commonality of perspective. The latter probably is important because it provides the common ground for successful communication and collaboration. Our cognitive science students will most likely work in multidisciplinary work environments, whether at universities or in industry. Consequently, it seems important for us as teachers to prepare them for the requirements of work in such environments, by, among other things, giving them some first hand experience of the different perspectives or cultures that they will encounter in their professional lives.

5 Design of a program based on these views

To put what I will describe below in context, I will first say a few words about the Swedish undergraduate education in general. All countries have their differing university traditions. One aspect of the Swedish’ system that makes it differ from most other countries, is that the Master’s level is a part of the undergraduate and not the graduate level. Another, and in the present context more important, is that much of the undergraduate teaching takes place within pre-defined three to four year educational programs, often with a strict progression of courses to be taken during the years, and especially the initial ones. There are certainly both pros and cons with this, but one advantage is that it makes it possible for us as teachers to control the order in which courses are taken, and let theoretical and pedagogical reasons influence these decisions. We have tried to make active use of this possibility in our design of the cognitive science program.

There are two aims underlying the design of the program, related to the view of cognitive science described above. First, to give the students some first hand experience with all three scientific traditions or cultures we have defined, while at the same time letting them specialize in at least one of these to a level of proficiency and professional competence that makes it possible for them to perform independent first class work within that tradition. Second, to provide opportunities for the students to integrate the different sub-parts into a coherent view of cognitive science where the whole is something more than the sum of its constituent parts.

These two goals are obviously conflicting, at least on a surface level, since the first is about learning what characterizes ‘pure’ empirical cognitive science etc, whereas the second is about merging these into a larger whole.

We all know that ‘First impressions count’, and the truth in this has been demonstrated by Cognitive Science research (e.g. Asch, 1952). And educational experience too tells us that students’ worldview will be most strongly influenced by the very first courses taken. Consequently, we have deliberately structured the sequence of the first two years of courses to give an as balanced as possible mix of the different methods and domains. Our program has an emphasis on the ‘higher’ levels of cognitive science, and in the three subjects psychology, linguistics/communication, and computer science/AI. Conse-

[2] “Anything that can be learned by a normal American adult on a trip to a foreign country (of less than one year’s duration) can be learned more quickly, cheaply, and easily by visiting the San Diego Public Library.”(Simon, 1996a), p 306. It is interesting to note here the parallelism between Simon’s view on this, and his belief in the possibility of the creating artificial equivalents of human intelligence based on a symbol processing architecture.

quently, almost the entire first one and a half years have the focus on basic courses in psychology, linguistics, and AI, and in courses in empirical research design and statistics, logic and discrete math, and programming. By this we want the students to get an early first hand knowledge of the different scientific traditions associated with our three topic areas, hoping thereby to avoid having e.g. students with a deep background in psychology viewing the later AI course through their 'psychological glasses', and seeing AI as some kind of inferior psychology (speculative and too weak empirical evidence, based on toy examples and simplified views on cognitive processes etc). Or making them to view everything they learn about psychology through their AI and programming glasses, just because that was what they first studied.

The first two years of courses taken follow a pre-described obligatory path. After these two years the students can branch out into different specializations. This does not, however, mean that the students specialize into one sub-discipline. They must continue to take courses in all disciplines and also courses in cognitive science that integrates the perspectives, but they emphasize and specialize in one or more sub-area of cognitive science. This specialization is strengthened by the students first hand experience with other scientific traditions, since this helps them seeing the strength and weaknesses of their own sub-field by being able to view it from also an outside position. This is in a sense similar to the traveler who gains a deeper understanding of his own country and culture by encounters with the other countries and cultures he has traveled through.

Our aim is that when the students leave the university, they will do it with an understanding of not only the possibilities and limitations of their own sub-fields, but as importantly with an implicit understanding of the 'thinking style' of programmers, experimental scientists, etc.

This is based on our belief from our own careers in the evolving field of cognitive science, that the major stumbling block for successful communication between e.g. computer scientists and psychologists, is not lack of knowledge of the theories in the different fields; most academics can, after all, read books. Instead, the culture clash comes, as we also could expect from cognitive science research, from the unspoken, non-verbalized (and perhaps non-verbalizable) underlying 'taken for granted' assumptions of the different scientific traditions. As pointed out above, we believe that you can never really learn what it is like to live in another culture by reading about it, you have to live there, Likewise, we believe that the only way for our students to understand the different scientific cultures of cognitive science, is to live them. And to do it early on in their university years.

6 Integrating the Diversity

But we are hopefully teaching cognitive science, and not just psychology + linguistics + computer science, with some add-ons of philosophy, neurology and anthropology. The students need a cognitive science perspective on their studies. All through the four years of study, but with increased emphasis after the first one and a half years of studies, we try to help the students forming a coherent view of the field of cognitive science as a whole. The emphasis here is on making the students finding their own perspective on this, not presenting them with ours. There exists no longer one dominant view of cognition or cognitive science, as it was in the hey-days of information-processing psychology, symbolic AI, and functionalism in philosophy of mind. But even if this means that we cannot tell the students how everything fits together, we shouldn't leave it to them alone the task of creating a structure of the field at large. Instead we try to provide courses that serve as vehicles for their work on this. I will here give an example of one such course.

6.1 The Applied Projects Course[3]

In the project course, where the students work in groups of 6-7 students, the aim is to give them an opportunity to use their theoretical and methodological knowledge in working on an applied problem. Furthermore, we do not enforce all members of the group to be equally involved in all aspects of the project, e.g. if some students would prefer to program they can do so within the project. However, the project as a whole *must* be coherent and integrate at least two sub-areas of cognitive science, such as Psychology (empirical) and Computer Science (design/modeling). This means that the group of students, although individually working within maybe only one sub-area, must view the problem as a Cognitive Science project.

We also want the students to realize the difficulties of being a cognitive scientist once they have graduated. This is achieved by having two supervisors from different research areas. They are explicitly instructed to pursue their own view on how to best handle the research question raised in the project, which means that the students occa-

[3] This course was developed by Arne Jönsson, and the description here is based on an unpublished manuscript by him.

sionally will have two of their teachers arguing in front of them on the best way of doing their project work. When they leave the university, our students will never work in a homogenous group of co-workers, and with superiors sharing the same educational background as theirs. This of course also forces the students to use their own judgement on how to pursue with their work, since they cannot simply do what their teachers tell them to do.

7 Some possible revisions of the map

In the first part of this paper, I pointed out that the picture of cognitive science I was about to present was a provisional one. And while I believe that it has well served its purpose of giving a reasonably coherent framework for the development of our cognitive science educational program in Linköping, like all provisional 'truths' it will need to be revised. In the final section I will mention some possible extensions and/or revisions that I am presently contemplating.

First, should not the two 'methods' I have called formal research and design research be grouped together? In both cases, we are developing or designing formal models (in a wide sense) of cognitive processes. Perhaps including the process dimension by implementing these models as running programs should better be viewed as a difference similar to the one between e.g. quantitative and qualitative empirical research. While I believe that this argument has much merit, if viewed from within a pure basic research scientific perspective, I am less convinced that this is the case if we look at applied cognitive science. It is my impression that the development of implemented cognitive artefacts is enough of a separate 'scientific culture' to merit it being kept separate from the other two areas discussed here. But this is definitely still an open question.

Second, the listings of different sub-domains within cognitive science given in this paper, both those of my own and those of others, do not seem to have any principled structure to them. Gardner, who also argues for a non-unified science of cognitive science, suggests that future or emerging sub-areas will not comprise of the present ones like psychology, linguistics and the like, but rather on more topic based sub-divisions like language, music, social knowledge, logical thought, and more focused sub-domains like syntactic processing, early phases of visual processing, or the perception of rhythm (*ibid.* p390). The problem with this is not only that there does not seem to be any limit to the number of possible subject areas, but perhaps even more so no way of grouping these into larger categories.

My impression is, however, that one such dividing line is perhaps currently emerging within the cognitive science community, which perhaps merits being viewed as a 'cultural' dimension in the sense used in this paper. Im am thinking of a clustering the field into two major sub-divisions; one connecting cognition 'proper' with its underlying strata (neuroscience, sub-symbolic computation), and another connecting to the physical and social environment (situated cognition, activity theory, etc).

On the other hand, perhaps the line of thinking used in this paper should not be stretched too far? While serving a heuristic value given the present state of cognitive science, at least in the educational domain, what the field probably needs is a re-structuring of its content domains along completely different lines than the ones used hitherto. But such an ambitious project is beyond the scope of the present paper, as well as its authors abilities.

Acknowledgements

The ideas in this paper have been shaped and influenced through many years of collaboration on research and teaching with friends and colleagues at the Natural Language Processing Laboratory and Linköping University's Computer Science Department. Special thanks to Arne Jönsson, current director of studies for the Cognitive Science program in Linköping, for lots of serious fun over the years.

References

Asch, S. (1952). *Social Psychology*. Englewwod Cliffs, NJ: Prentice-Hall.

Dahlbäck, N. (1991). *Representations of Discourse - Cognitive and Computational Aspects.* Unpublished Ph. D. Thesis, Linköping University, Linköping.

Dahlbäck, N. (1999). *The Design of and Undergraduate Program Based on a View of Cognitive Science as a Society with Three Methodological 'Cultures'.* Paper presented at the Workshop on teaching Cognitive Science at AISB'99, Edinburgh.

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In R. J. Sternberg & J. Davidson (Eds.), *Mechanisms of Insight* . Cambridge, MA: The MIT Press.

Gardner, H. (1987). *The Mind's New Science (2nd edition).* New York: Basic Books.

Helmholtz, H. v. (1962 (english transl)). *Treatise on Physiological Optics, vol III* (J.P.C. Southall, Trans.). New York: Dover.

McTear, M. F. (1988). *Understanding Cognitive Science*. Chichester: Halsted Press.

Pylyshyn, Z. (1984). *Computation and Cognition: Toward a Foundation for Cognitive Science*. Cambridge, MA: The MIT Press.

Schunn, C. D., Crowley, K., & Okada, T. (1998). The growth of multidisciplinarity in the Cognitive Science Society. *Cognitive Science, 22*(1), 107-130.

Searle, J. (1980). Minds, Brains, and Programs. *Behavioral and Brain Sciences, 3*, 417-424.

Searle, J. R. (1992). *The Rediscovery of the Mind*. Cambridge, MA: Bradford Books.

Simon, H. A. (1996a). *Models of my life*. (2nd ed.). Cambridge, MA: The MIT Press.

Simon, H. A. (1996b). *The Sciences of the Artificial (3rd edition).* Cambridge, MA: The MIT Press.

Simon, H. A., & Kaplan, C. A. (1989). Foundations of cognitive science. In M. Posner (Ed.), *Foundations of Cognitive Science* . Cambridge, MA: The MIT Press.

Stillings, N. A., Feinstein, M. H., Garfield, J. L., Rissland, E. L., Rosenbaum, D. A., Weisler, S. E., & Baker-Ward, L. (1987). *Cognitive Science: An Introduction*. Cambridge, MA: The MIT Press.

Wolpe, J. (1958). *Psychotherapy by Reciprocal Inhibition*. Stanford: Stanford University Press.