If Cognitive Science is Multidisciplinary, Which are the Disciplines? Cognitive Science as Three Methodological Cultures

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Abstract

A 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 three dimensions, a content or domain dimension (e.g., language, problem solving etc, and subsets of these), a levels dimension (from synapse to situated/distributed cognition) 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'. In the final section an application of this view in the design of Cognitive Science education is presented.

Introduction

In an interesting analysis of papers published in the journal *Cognitive Science* and at the *Annual Meeting of the Cognitive Science Society,* Schunn, Crowley and Okada (1998) discuss whether Cognitive Science is as multidisciplinary as was its aim from the beginning. Von Eckhardt (2001) address one question that emerges from the work of Schunn et al, namely which conception of multidisciplinarity should be used when considering this issue. Von Eckardt suggests that there are two potential views on multidisciplinarity, a localist and a holist view, where localist essentially means that each individual contribution, e.g. each paper published, should be of a multidisciplinary character, and holist essentially means that the entire field is multidisciplinary, even if individual contributions are not.

The present paper address another issue that emerges from the work of Schunn et al, namely which are the different individual disciplines that we should consider be the different parts of the multidisciplinary field of Cognitive Science.

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 on-going 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 (1984) 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 sub-fields of cognitive science is that it conflates methods and topic areas. 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 in their view 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 methodological traditions in the field. In addition to these two dimensions, it is useful to distinguish between different *levels* of cognitive processes (from synapse to situated/distributed cognition). In this paper I will concentrate on the methodological dimension, but will also at the end of the paper address some aspects of the content and levels dimensions.

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.

If this sounds rather self-evident to most scholars today, one can note that this has not always been the case. Boole considered his work on logic as a part of an endeavor to figure out the basic laws of thought, and to found them on the principles of logic. The logic operations he described were termed by Boole "the laws of though" (c.f. Gardner, 1984, 143). An approach to the study of human thought quite different from current non-logic heuristic approaches (e.g. Gigerenzer and Todd, 1999).

The third category suggested here, the constructive or model building (sometimes called design science, or the sciences 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 artifact 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 that not belong to cognitive science, 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.

But 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 artifacts 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.

A Clustering of the Sub-fields of Cognitive Science?

If we want to say something about the different parts or sub-sets of Cognitive Science, we first need to delimit or define the field itself. And this description should not be biased towards or against any particular theoretical view or perspective, e.g. the representational or computational theory of mind.

As an approximate definition of the subject field of cognitive science could perhaps 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.

Note 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, in a sense, an attempt to put the rationalistic heritage in cognitive science on its head.

But if this is accepted as a provisional definition or description of the field at large, which are its possible sub-fields? Gardner (1984), who is one of the authors that have argued 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 (Gardner, p390).

While I am sympathetic to the idea of separating out the content of the study object from the methods used, and of not using traditional scientific disciplines as the units or building blocks when describing the field of Cognitive Science, I think that a problem with Gardner’s way of describing 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. I 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). The suggestion here is that we are currently seeing a grouping or clustering along the levels dimension mentioned previously into these two sets. But this is not based on an empirical analysis similar to the one by Schunn et al, and is therefore presented here more as a hypothesis than anything else. (Note that this is a different kind of grouping than Marr’s (1982) well known three levels, or the similar structure presented by Von Eckardt (2001)).

For whom is this of any interest?

For most practitioners in the field, working in established research areas, the issue discussed here 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 what Searle (1980) called ‘strong AI’ 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 is written perhaps more from an applied perspective. In the final part of this paper I will therefore illustrate how the view presented here has been applied in the development and design of the Cognitive Science program at Linköping University.

Designing an Undergraduate Program in Cognitive Science Based on this View

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 anything 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.

One consequence of the argument presented 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.

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.

Methods training as a cultural practice

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[1]).

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.

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. Consequently, 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.

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 that the major stumbling block for successful communication between e.g.

[1] "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.

computer scientists and psychologists in the evolving field of cognitive science, 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.

A Final Comment

Like Von Eckardt (2001), my aim with this paper is to engage in the “productive dialog regarding the development of the Cognitive Science Society and the discipline of cognitive science itself” that Shunn et al hope their work will inspire (Shunn et al, p. 128). And it is in that spirit that I have presented the idea of describing cognitive science as a multidisciplinary field of research on the information processes of natural and artificial agents’ interaction with the physical and social environment, and the idea that the field is best structured along a content, a levels, and a methods dimension of the kinds described here.

One consequence of this view is that when judging whether work in cognitive science is multidisciplinary or not, we should not primarily look at whether it is done by people from different departments, or from people judging themselves as belonging to different disciplines, but instead focus on whether the work varies along the dimensions described here. And one of the reasons for my stressing the importance of the methods dimension in this paper, is that my some 20 years of experience of working in multidisciplinary research environments suggests that working together with colleagues from another methodological tradition presents both the largest challenge to get it to work, and the greatest pay off, if it works.

However, while serving a heuristic value given the present state of cognitive science, at least in the educational domain, I make no claims that this is the final word. But I do believe that for the field of cognitive science to develop beyond its present rather fragmentary understanding of its study object and itself, it needs a better way of self-understanding than the original conception of an intersection of the six sciences of psychology, neuroscience, artificial intelligence, linguistics, philosophy, and anthropology[2]. And I hope that the ideas put forth here can inspire further work on this.

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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.

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.

Giegrenzer, G & Todd, P (1999) *Simple Heurstics that Make Us Smart* Oxford: Oxford University Press.

Marr, D (1982) *Vision*, New York: Freeman.

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.

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.

Von Eckardt, B (2001) Multidisciplinarity and Cognitive Science, *Cognitive Science,* (25) 453-470.

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

[2] It is for instance interesting to note that for the present conference, each paper is asked to be classified as belonging to a particular field, and the ones listed are six ‘traditional’ ones, plus computer science, biology and education, all of which are traditional scientific disciplines. It is not possible to classify a contribution as ‘cognitive science’.