Advanced Topics in Cognition, 2018

Graduate Course, HBCSE, TIFR
2018-2019 – Semester 1
Monsoon 2018

Coordinator: Sanjay Chandrasekharan
Tutors: Deborah Dutta, DurgaPrasad Karnam, Chaitanya Usrekar

Credits: 4
Duration: 16 weeks, class starts on 10th August (3-5 PM)
Time: Tuesday, 2-4 PM, Thursday, 11-1 AM (Saturday classes will make up for any holidays).
Location: Room 102 / 217, Main Building, Homi Bhabha Centre for Science Education
Important date: *Final paper due on December 15*

1. Summary

The human mind emerges from extremely complex biological activity across a many-layered system, involving neurotransmitters, hormones, genes, neurons, synapses, cerebrospinal networks, the cortex, the enteric [gut] nervous system, attention, perception, memory, action, motivation, emotion, language, reasoning, imagination, intuition, consciousness, the self, and many other components.

Interactions between these many layers, as well as between these layers and the environment (chemicals, signals, cellular structures, symbols, materials, actions, people, society, norms, culture...), constantly changes the mind. Feedback systems, both between the layers and the rapidly changing interactions, create many more layers of complexity. Further, any attempt to study the mind requires the mind to understand itself, which creates a recursive process that changes the complex activity that is the mind.

This complex, dynamic and recursive nature makes the mind the most complicated machinery known to mankind.

Despite the daunting complexity and the methodological challenges involved, a range of theoretical and empirical approaches have been developed in the last hundred years to scientifically study the mind. These approaches help hold down -- to some extent -- the shadowy and shape-shifting beast, and allow systematic studies to understand its workings.

This course will examine a subset of this range of theoretical and empirical approaches, focusing on just the nature of cognition (symbolic cognition, connectionism, distributed cognition, dynamic systems, ecological psychology, situated robotics, situated cognition, embodied cognition). The focus will be on recent theoretical approaches, particularly distributed and embodied perspectives, and the cognitive and brain mechanisms that support these approaches.

To critically engage with these different theoretical approaches, each will be evaluated, to see whether the proposed approach can provide interesting answers to the following two focus questions related to education:

1) What are the cognitive and neural mechanisms that support the learning and practice of science?

2) How does the process of science education change human cognition and the brain, such that new discoveries and technologies can emerge from this change?

A more operational version of these focus questions is developed in Section 10. These operational versions will be the ones actually used to do the evaluation of the cognition theories.

2. Learning Objectives

The primary objectives of the course are:

1) provide alternatives to the standard information processing model of cognition
2) explore what these alternate views suggest about the nature of learning and education
3) develop a mechanism account of imagination, particularly in science and engineering

For participants who do not intend to pursue advanced research in cognition and related topics, the course would be useful in developing critical skills needed to pursue social science research in general. Particularly:

1) how to pull out key arguments from complex text
2) how to evaluate the merits of an argument
3) how to relate a theoretical perspective to a given topic, and understand its implications
4) how to critique an established view, and develop and defend an alternate thesis

3. Reading Material

The course requires significant reading (60-100 pages a week; ~60 papers). The readings will be a mix of philosophical, experimental and modeling papers, as well as popular articles. Some papers will be technical, but the discussion will focus on theoretical issues rather than technical details. The title for each week in the course plan below indicates the general gist of the articles.

Soft copies of all readings will be provided (pdf). Each week's readings are in a separate folder, with 4 (sometimes 5) core readings. These are given numbers 1 to 4-5, at the end of the filename. The key points would be easier to grasp if the papers are read in this order. This ordering is also provided in the course plan below. Most folders have a subfolder named “Extra”. This contains a few other papers and material to pursue if the topic is found interesting.

The readings are difficult, and may require more than one pass. Previous students have found discussing the material once among themselves before coming to class quite helpful. This possibility should be explored.

4. Class Structure

The class will be participant-driven and discussion-based, with some group work. Class strength will be limited to around 15 active participants. Each week's readings would be presented by a team of two participants. This cycle will continue throughout the course. All participants are requested to read the text beforehand, so that there is a common base to discuss and critically analyse the issues raised by the papers.

All participants have to turn in a “Comments and Queries” (C&Q) document to the Tutors before the class, focusing on the week's/session's readings. See Note 1 below for guidelines on what is expected in this document. The Comments and Queries are expected to be used to frame the discussion in the class. Participants who are presenting the material in a given week need not submit this document for that week, but generating these would be useful in guiding the discussion. The Tutors will provide feedback on your C&Q documents and the presentations. See Note 2 below for guidelines on the structure of presentations.

It would be good to start thinking about a problem of your choice sometime around the third week of the course, as this would help ground your C&Qs better. This would also help develop a term paper .

5. Assessment

Students taking the course for credit will be graded on the basis of a final term paper (50%) as well as the Comments and Queries document, presentations and class participation (50%). Each C&Q/presentation carries 10 marks. Your C&Qs and presentations together should total a minimum of 10 submissions.

The final term paper should preferably connect the student's interest in education with one of the topics covered in the course. A rough outline of the term paper should be submitted by November 15. See Note 3 below on what is expected for the term paper.

6. Course Plan

Introduction (August 10, 3-5 PM)
Course outline, backgrounds & interests, presentation schedule, groups, primers etc.

Week 1 (August 14, 16)
Behaviorism and The Standard Model of Cognition
Watson, Miller
Newell, Skinner

6.1. Reforming the Standard Model

Week 2 (August 21, 23)
Connectionism
Garson, Hinton
Sidenberg, Hayes

Week 3 (August 28, 30)
Distributed Cognition
Hutchins, Hutchins, Bohannon
Kirsh, Vygotsky

Week 4 (September 4, 6)
Possible Mechanism underlying use of external structures: Incorporation of external structures into the body-schema
Maravita, van der Hoort, Burns
Yee, Hanakawa

Week 5 (September 11, 13)
Possible Mechanism underlying the social distribution of cognition: Resonating others' actions
Knoblich, Decety
Taylor, Thomas

Week 6 (September 18, 20)
Distributed cognition 2: Language
Ong, Skeide
McCormick-Miller, Winawer

Week 7 (September 25, 27)
Possible mechanism: acquired synaesthesia
Bach-Y-Rita, Thaler,
Ramachandran, Bor, Ward

Week 8 (October 2, 4)
Distributed Cognition 3: Actions and building
Kirsh, Sinclair
Martin, Chandrasekharan

6.2. Rejecting the Standard Model

Week 9 (October 9, 11)
Dynamic Systems
Van Gelder, Smith
Thelen, Sievers

Break (October 16,18)

Week 10 (October 23, 25)
Ecological Psychology
Reed_Gibson, Tucker
Ramenzoni, Abrahamson

Week 11 (October 30, November 1)
Situated Robotics
Brooks, Braitenberg
Kirsh, Chandrasekharan
See the robotvideos folder for some implementations. Also see the bugworks simulation.

Week 12 (November 6, 8)
Situated Cognition
Kirsh, Lave
Cobb, Cleeremans

Week 13 (November 13, 15)
Embodied Cognition
Glenberg, Schubotz
Thomas, Bak

Week 14 (November 20, 22)
Evidence for embodied cognition: The role of the body in perception, imagination, language, numerosity and equations
Landy, Wohlschlager
Matlock, Domahs

6.3. An Ongoing Synthesis

Week 15 (November 27, 29)
Towards a theory of science cognition
Chandrasekharan (Beyond Telling), Rahaman
Chandrasekharan (Becoming Knowledge), Glenberg

6.4. Some Emerging Trends

Conclusion (December 4)
Epigenetics, the Immune-System, the Microbiome, the body as 'frozen' cognition
Dobbs, Zimmer, Costandi, Ravindran, Pollan
Reflection
Dinner

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7. Note 1: Comments & Queries

1) A summary of the papers is not expected. If summarising helps you in understanding the material, you should still do it. But keep that part as a separate file, and refer to the summaries when you run into problems or get stuck while conceptualizing/writing your final paper/proposal/thesis.

2) Queries with the following structure are not useful: "how can we use (say) mental imagery for education/design"? There is no clear answer to this question, because it is too general. It would be better if you turn such questions into something like: "in math/science education, there is this problem of XYZ, and the author's ideas seem to imply that strategy ABC would be useful/would not work, is this right?" or something along these lines. To do this, you will have to do some focused thinking about the author's ideas, and apply it to a problem you are familiar with. If you have a question like this, other people can contribute to the discussion, and maybe even help you solve a problem.

3) Comments along the lines of "this view is interesting", "the author has done a good job" etc. are not useful. Comments should show close engagement with the ideas in the papers. So something like "the author's position seems to contradict/support the position of (another) author X in the following way" or "the data seems to be showing X, but it does not seem to support the author's claims" or "the author argues for X, but it has the following implication, which is undesirable" etc.

4) Before writing your C&Q, try to think a little more deeply about the implications of the ideas presented by the authors, and also try to connect their ideas with other things you have read, in the class or outside. This would help you come up with C&Qs that are closer to the description above.

8. Note 2: Presentations

All presentations should follow the structure below:

1)What is the major claim of the paper?
2) What design/data/arguments support the claim?
3) How well does the design/data/argument support the claim? What are the main problems?
4) What would be other/better ways to support the claim?
5) What implications follow from the claim, particularly for education?
6) Any details you would like to highlight

Using 1 slide for each of these questions would be the ideal format. Aim for a 15 minute presentation for each paper. Presentations for each day can be upto 30 minutes in total.

9. Note 3: Term Papers

The following points should be kept in mind while picking your topic for the term paper, and during writing of the paper.

1) The paper should be around 15-25 pages, single space. Why is this an important point? Because you should choose a topic that *requires* that much space for discussion. If you choose a very broad topic, you will not be able to do justice to it in this amount of space. If you choose a very narrow topic, you will not have enough things to say to fill that amount of space. The size of the paper is a good way to "scope" your topic.

2) The paper should have an argument. That is, it should have some clearly articulated premises, and a conclusion that follow from these, preferably with some discussion of data/results that support the conclusion. For instance, you can argue that neuroscience research is irrelevant for science education. Or you can argue that imagery research can inform physics learning. But you should give reasons for why you think this is the case. The requirement for an argument means the paper cannot be a literature review, a discussion of a new approach to science education, or an evaluation of a new technology. The argument structure makes the term paper somewhat like a miniature thesis, or a journal paper. If you write a few of these during a course work, you will be able to deal better with your research proposal and thesis.

3) Writing the paper should make you think. This is sort of implicit in the previous point, as you cannot develop an argument without thinking. However, in academic writing, particularly in humanities and social sciences, apart from the thinking needed to develop the argument, you also think *through writing*. This involves being able to see counter examples and counter arguments as you develop your argument in text, and then finding ways of countering them. This process can take a life of its own, and might lead you into many tangents that prevent you from developing your core thesis. So part of the skill here is learning how to pursue this process in a controlled fashion.

4) Ideally, you should pick a topic that is related to a possible thesis topic you have in mind. This way, you can reuse the thinking you do for the term paper while developing your research proposal.

5) The paper should have an abstract (~150 words) that summarises its key points.

6) The term paper is due on 15th December midnight. This is a hard deadline, as I have to turn in the

marks by end of December.

7) Two alternatives to term papers could be: 1) Doing an experiment, 2) Reveiwing a book. Texts based on these would also need to follow the above structure. Further, you need to discuss ideas for these with the instructor beforehand, and develop a clear outline of what you will be doing.

10. Focus Questions: An Operational Framing

As indicated in the summary section, the two focus questions below will be used to judge the possibilities and limitations of each theoretical framework.

1) What are the cognitive and neural mechanisms that support the learning and practice of science?

2) How does the process of science education change human cognition and the brain, such that new discoveries and technologies can emerge from this change?

However, theories of human cognition are based on components and processes such as perception, action, information, simulation, etc., and the above questions do not relate to these components. A more operational framing of these questions is needed, where the complex processes of learning and practice of science is unpacked, and characterised in a way that these processes can be related to the accounts of human cognition.

We will use the characterisation below, which, admittedly, is limited in scope. However, it has two advantages. One, it captures a significant chunk of science practice and learning. Two, it includes many key elements that are needed to evaluate existing theories of human cognition.

> *Modern science deals with entities and phenomena that cannot be directly perceived or acted on, because they are too small (atoms, DNA, cells, etc.), too big (galaxies, stars, tectonic plates, etc.) , happen in timescales that are difficult to perceive (milliseconds – chemical reactions, millennia – evolution), and are complex (feedback loops between levels and timescales).*
>
> *How did science discover, and gain control of, such entities and phenomena, which were not known, or available for manipulation, five hundred years ago?*
>
> *One answer is that these entities and patterns are imagined, described and manipulated using abstract external representations, such as equations, graphs, models, simulations, theories, etc., and experimentally investigated using complex and opaque instruments, which themselves embed abstract concepts and mathematical models.*
>
> *Learning and practicing modern science (and technology) thus requires learning to:*
>
> *1) Imagine detailed mental models*
>
> *2) Transform external models and related representations*
>
> *3) Integrate the mental models and external models*
>
> *These three skills form the core of Model-Based Reasoning (MBR), which is now considered*

the dominant component of scientific reasoning.

External representations (ERs) -- symbolic elements that stand in for the actual entities and phenomena (such as diagrams, graphs and equations) -- are at the core of Model-Based Reasoning, as ERs help us understand and analyse these imperceptible and complex entities and phenomena, at different spatiotemporal granularities.

Ideas and information in science are thus distributed across these ERs, and learning and practising of science is impossible without gaining expertise in interacting with ERs, thinking and imagining with them, and learning to generate them. The ability to use and generate ERs in an integrated fashion, as well as perform transformations on the ERs, is termed Representational Competence (RC). RC comprises of the following non-exclusive and interrelated set of skills:

(a) Integrating internal and external representations, as well as different external representations
(b) generating ERs appropriate to the situation or problem
(c) communication using ERs
(d) reasoning using ERs
(e) choosing appropriate ERs based on the need of the situation/problem
(f) understanding and describing the different roles of an external representation in relation to other ERs
(g) critiquing ERs in terms of their strengths and shortcomings, etc.

In this characterisation, learning and practicing of science can be understood as the development and deployment of RC, i.e. the ability to use, transform and generate ERs in an integrated fashion.

This minimal, and limited, characterisation of science practice and learning provides a way of asking the two focus questions above at a more operational level, such that the new questions can be used to evaluate theoretical accounts of human cognition. The operation versions of the two questions are below:

1) *What are the cognitive and neural mechanisms that support the learning and practice of external representations?*

2) How does the process of learning to use and generate external representations change human cognition and the brain, such that new discoveries and technologies can emerge from this change?

These two questions will be used at the end of each week, to evaluate the theoretical account of human cognition that we encounter in that week.