Proposal for Interdisciplinary Program in Cognitive Science

Preamble

One of the most pertinent questions to have plagued human civilisations since ages concerns the nature of the human/animal mind. A variety of disciplines have tried to engage with this question since times immemorial. Psychologists have directly studied the mind in terms of mental processes like thinking, reasoning & decision making. Computer scientists have explored how these processes could be simulated & modeled in computers. Evolutionary biologists and anthropologists have speculated about how the mind has evolved. In fact, there are very few academic areas that are not relevant to the study of mind in some way.

Cognitive science is an interdisciplinary field that attempts to provide a framework to the various facets of the enquiry into the nature of the human mind. The field lies at the intersection of several other disciplines, including philosophy (knowledge representation, logic), psychology (basic human cognition, perception and performance), computer science (computational theory, artificial intelligence and robotics), linguistics (theories of language structure) and cognitive neuroscience (brain mechanisms for intelligent behavior). Typical research areas of cognitive science include reasoning and decision making, language comprehension and production, language acquisition, vision, attention, learning & memory, goal directed movement in complex environments and consciousness. In more recent times, Cognitive Science has also brought together various fields of engineering by providing insights about user (humans) behavior and cognitive processes to help in human-computer interface design and enhancing the usability of various products, i.e. usability engineering.

Cognitive science also studies behavioural deficits due to brain trauma, congenital or other reasons. Protocols for identification and rehabilitation form another important facet of this science.

Cognitive Science as an Academic Discipline

Over a hundred universities around the world are running an academic program in Cognitive Science. Typically, such a program offers Masters and PhD. Degrees and is run as a partnership of multiple disciplines and academic departments.

In India, also, we have post graduate programs in Cognitive Science, offered at Centre of Behavioral and Cognitive Sciences (CBCS), University of Allahabad; Centre for Neural & Cognitive Sciences, Hyderabad Central University; Centre for Cognitive Science, IIT-Gandhinagar; School of Cognitive Science, Jadavpur University and Indian Institute of Speech and Hearing, Mysore. Major institutions with more emphasis on neuroscience include National Institute of Mental Health and Neurosciences (NIMHANS), National Brain Research Centre, Centre for Neuroscience (IISc), SN Pradhan Centre (Calcutta University). There are a large
number of medical institutions that work with patients with cognitive disabilities or deficits. In addition many universities have departments of psychology and linguistics where specific aspects of cognitive science are being pursued.

Moreover, the Department of Science and Technology, Government of India, has recognized Cognitive Science as the fourth pillar of Science and Technology in India. Consequently, the DST instituted a highly focused program to fund and facilitate academic research in cognitive science under the ‘Cognitive Science Research Initiative’ in 2008 under the 11\textsuperscript{th} 5-year plan. The DST - CSRI funds several Individual R & D projects, PhDs and Post-Doc fellowships throughout the year. An Association for Cognitive Science has been incorporated and has already organized three national conferences in 2014 (New Delhi), 2015 (IIT Kanpur) and 2016 (IIT Gandhinagar). We have also organized a methods workshop in August 2016 funded by CSRI, DST.

At IIT-Kanpur, a course 'Introduction to Cognitive Science' has been running as an elective for a number of years. Other courses falling in the purview of the cognitive sciences have also been running in various departments of IIT-Kanpur for several years, for example in linguistics, neuroscience, cognitive psychology and computational modeling.

**Cognitive Science at IIT-Kanpur**

As Cognitive Science is gaining prominence as an interdisciplinary field, around the world and in India, we propose the formation of an Inter-Disciplinary Program in Cognitive Science at IIT-Kanpur. The institute is in a good position to start a research program in cognitive science since several faculty (see participating departments and faculty below) based in different departments have research interests which are in this area. This will allow participating faculty and students to come together in a cooperative and focused research program in cognitive science. Given the growing popularity and demand of courses dedicated to study of cognitive science, there is every possibility that the IDP will gradually grow into a full department.

The Inter-disciplinary Program in Cognitive Science at IIT-Kanpur will seek to offer a Masters (MS) and a PhD Degree in Cognitive Science.

**Prospects for Graduates in Cognitive Science**

Cognitive Science programs around the world are highly research oriented and that is why a lot of students pursuing a Masters’ or a PhD in Cognitive Science choose to continue a research career in the field of cognitive sciences and allied disciplines. However, many jobs are also available for those who turn to industry after completing their respective degrees. Opportunities are available in the fields of cognitive computing, natural language processing, design, usability research, human factors, Human-Computer Interaction (HCI), cognitive and behavioural rehabilitation and advertising.

In the past, students specializing in cognitive science have secured placements in the fields of decision-making, game theory, neuro-economics, Human Computer Interaction, usability design, user experience, in some of the companies listed below:
One of major strengths of an IDP in Cognitive Science at IIT-Kanpur will be the participation from so many departments/disciplines at once. To the best of our knowledge such an interdisciplinary program is currently not present at any other institution in the country. This would also place us in a position to get the best students interested in pursuing research in Cognitive Sciences in India.

**Educational Objectives of the IDP in Cognitive Science**

IIT-Kanpur takes pride in the strong academic skills and research expertise at the institute. In line with the same, the IDP in Cognitive Science will encourage the students to:

- Acquire strong empirical and theoretical background in one or more areas of cognitive science.
- Inculcate analytical and technical skills to conduct and critically examine research.
- Develop ability to conduct original research in chosen area.
- Gain experience of participating in collaborative lab-based community from varying backgrounds.
- Develop an application and innovation based perspective towards research to ensure greater societal and industrial impact.

**Degrees Proposed**

- MS (Cognitive Science)
- PhD (Cognitive Science)
- Integrated: (B.Tech. (X) + MS (Cognitive Science))

**Program overview**

**MS in Cognitive Science**

Given the interdisciplinary nature of cognitive science and the amount of emphasis on research, there will be two components in the MS Cognitive Science program, i.e. a course component and a research component. While the course component will allow the students to take a number of compulsory course and choose from a variety of electives, the research component will require students to complete a research thesis,
under the supervision of one or more participating faculty, addressing a problem in the field of cognitive science using empirical, theoretical/computational, or a mixed approach.

**Eligibility Criteria**

- Bachelors or Masters Degree in Cognitive Science or related disciplines including Psychology, Neuroscience, Bio-sciences, Mathematics, Physics, Engineering, Medicine, etc.

**Entrance Examination and Entitlement to Scholarship**

Given that certain institutes like IIT-Gandhinagar, Centre of Behavioral Sciences, University of Allahabad are already holding nation-wide entrance examinations for intake of students, we could join with them to hold a Joint Entrance Examination in Cognitive Science, on the lines of the currently held JAM exam.

Students, who have qualified exams of national importance like the GATE, will be provided with scholarship obtained via the Government of India. Others coming just after bachelor’s degree will have to self-finance their expenditure.

There is however a proposal to request DST to initially support students in the MS program with scholarship.

**Requested Sanctioned Strength**: 14 each year.

**Program Format**

The incoming students will be first required to take a minimum of 4 Core Courses during the first two semesters, which will allow them a uniform entry point into Cognitive Science. These core courses will equip the students with a firm grasp over the various topics and questions in cognitive science. Also, these courses will familiarize the students with methods and tools to conduct research in their chosen area of cognitive sciences.

At the end of the first semester, each student will be asked to choose one of the participating faculty as a project advisor. The participating faculty will conduct a project course for the student, which will familiarize the student with the advisor’s research area. The project advisor will also help the student in choosing a research topic for the Master’s Thesis. Also, the project advisor may guide the student in terms of choosing the right elective courses keeping the interests and thesis topic in mind.

Students will have to take a minimum of 3 Elective Courses, from a variety of electives offered by participating faculty. Elective courses can be taken according to credit load deemed optimal by the student and her/his advisor, in a fashion that fulfills the minimum credit requirement and does not exceed the maximum credit requirement.

During the third and fourth semesters students will be required to carry out a research project under the guidance of one of the participating faculty members, which will carry 24 credits per semester. The research project is expected to lead to a Master’s
Thesis. The Thesis supervisor may or may not be the same as the Project Advisor chosen by the student at the end of the 1st semester.

Additionally, in order to get students acquainted with the latest research in the various fields constituting cognitive science, there will be a compulsory reading group. Participation in the reading group will be treated as a Seminar course. Other requirements will be as per the PG manual for masters program.

Proposed Credit Structure

As per the PG Manual at IIT-Kanpur, a PG student can register for 45 credits in a semester, which leads to 45 x 4 = 180 credits. This will be the maximum number of credits allowed to a student in the MS Cognitive Science program. However, the prescribed credit scheme is as follows:

Courses:
4 Core Courses x 9 credits = 36 credits
3 Elective Courses x 9 credits = 27 credits
1 Project course x 9 credits = 9 credits
1 Seminar x 6 credits = 6 credits
Total = 78 credits

Thesis:
Two semester equivalent of thesis Work x 36 credits = 72 credits

Total = 78 + 72 = 150 credits.

Proposed Course Structure

Semester I
CGS 401: Cognitive Processes I (T + L)
CGS 408: Tools in Cognitive Science (T + L)
BSE 656A: Neurobiology (T)
Project/Elective 1 (Recommended)

Semester II
CGS 402: Cognitive Processes II (T + L)
Elective 2
Project/Elective 1
Seminar
Thesis I

Semester III
Elective 3
Thesis II

Semester IV
Thesis III

**Doctoral Program (PhD)**

The Doctoral Program in Cognitive Science will aim to provide the state-of-the-art training in Cognitive Science to prepare the students for careers as scientists and teachers who will make contributions to society in academic or applied settings. Students will be expected to gain expertise in scientific issues and experimental, theoretical, and/or computational methods across fields of Cognitive Science. Programs of study for PhD students will be highly individualized; decisions about research and coursework will be made in close collaboration with a research advisor and graduate committee of each student. Students will be encouraged to collaborate with faculty members who are not their primary advisors.

**Eligibility Criteria**

a) Master’s Degree (or equivalent) in any branch of Engineering or Medicine.
b) Bachelor’s Degree in any branch of Engineering/Medicine.
c) Master’s Degree in Psychology, Philosophy, Linguistics, Cognitive Science, Biosciences, Mathematics, Physics or Chemistry.

All students in categories (b) and (c) should have obtained percentage marks (or equivalent) in the qualifying examination greater than equal to the minimum as currently laid down for different categories by the Senate. All such students must also have a valid GATE/NET or other scores as specified by the institute.

**Entrance Examination and Scholarship**

All students

**Requested Sanctioned Strength:** 30 (at any given time)

**Course Structure**

The course component of the doctoral program will require the students to take a minimum of 4 core courses, which will be common to the Master's Program. The students will be advised to take these courses as they are offered in the Master's Program. In addition, the students will be advised to take Elective Courses as per the credit requirements, deemed optimal by the Thesis Supervisor. Moreover, in each semester after the second semester students will be required to do a seminar which discusses advances in one of the core subject areas of cognitive science (this is item 1d below). The seminar course will be graded as satisfactory or unsatisfactory and no letter grades will be awarded. Students who have background deficits will be required to do extra courses as suggested by the program adviser (also see remedial courses below). Other requirements will be as per the current requirements for PhD students in the PG manual.
The thesis, which will be an original contribution in the area of cognitive science, will be done with at least one supervisor who is a participating faculty member in the inter-disciplinary program and possibly joint supervisors from other departments based on expertise.

Faculty:

The faculty resources in terms of individuals in parent departments exist. However, we require the following help from the parent departments:

a. Formal recognition of teaching, research and administrative load in the interdisciplinary program while assigning load in the parent department.
b. To strengthen the program we need recruitment of faculty in the parent department who can also participate in the cognitive science program. The institute should be willing to raise sanctioned strengths where needed. The program currently requires faculty in the areas mentioned below:

i. Artificial intelligence, machine learning, computational cognitive modeling, human computer interaction (CSE, EE).

ii. Experimental cognitive psychology, computational and cognitive linguistics, philosophy of cognitive science (parent HSS Psychology, Linguistics/English, philosophy).

iii. Cognitive and computational neuroscience (BSBE)

Currently, the participating departments include - CSE, HSS (Psychology and Linguistics), EE, BSBE and the following faculty are interested:

- BSBE: Drs Nitin Gupta (NG), Jonaki Sen (JS)
- CSE: Drs Nisheeth Srivastava (NS), Harish Karnick (HK).
- EE: Dr Tanaya Guha (TG)
- HSS (Philosophy): Drs A V Ravishankar Sarma (AVRS), Vineet Sahu (VS)
- HSS (Linguistics): Dr. Achla Raina (AR).
- HSS (Psychology): Drs Ark Verma (AV), Devpriya Kumar (DK), Shikha Dixit (SD).

Support required from the Institute:

Laboratories: The following are needed to be able to support the basic experimental component. These facilities can be created by adding equipment to already existing facilities in the parent department.

Cognitive Science Lab (Parent lab in HSS - cognitive psychology).
Additional equipment required: 5

i. Remote eye tracking system.
ii. EEG at least 128 electrodes.
iii. TMS system with localizer
iv. High-end workstations for psychophysics experiment and data analysis
v. Dedicated laboratories for conducting experiments using above-mentioned equipment’s.
vi. Dedicated seating/working space for masters and PhD students
vii. Scholarship for MS students without GATE/NET

The above is an initial list. Other faculty in Design and Mechatronics may join in once the program starts.

The cognitive science group has strong connections with all the other main cognitive science centers in the country and the group here expects to collaborate strongly with the groups in the existing centers.

**List of Courses**

**Core Courses**

- **Cognitive Processes I (CGS 401)**

  This course is basically meant to give the students the first introduction in Cognitive Psychology. The idea is to introduce students to the basic mental processes, on which the complex architecture of human mind and behavior are built. Students will be reading about basic theory and state-of-the-art research and models of: sensation and perception, motor-systems, attention, memory, language, emotion, object recognition etc.

- **Cognitive Processes II (CGS 402)**

  This course is aimed at providing students familiarity with higher cognitive processes. Building on the course in basic mental processes (CGS 401), students will be familiarized with higher order cognitive functions. Students will be taught about Thinking, Reasoning & Decision Making, Action and Perception, Executive Control Processes, and Emotion and Social Cognition.

- **Tools in Cognitive Science (CGS 408)**

  The course is aimed at training the students in the various research methodologies in cognitive science. The course will introduce the students to experimental design, mathematical and computational tools in cognitive science. The students will be introduced to methods of analyzing experimental data. Also, they will be introduced to behavioral research tools, eyetracking and EEG methodologies. This will be a theory and lab course where students will get a hands on experience of working with different methods.

- **Neurobiology (BSE 656A)**
The course is aimed at introducing students to the basic principles of neuroscience. The course will talk about both animal & human models of how various cognitive processes are realized in the human brain.

Elective Courses

The elective courses are meant to allow students to gain specialized knowledge and training in their field of interest. There will be a number of elective courses on offer every semester on the basis of the availability of participating faculty. Most of the elective courses will be cross-listed with participating departments, to share the teaching load in the parent department as well as the IDP. Also, students will be encouraged to take courses of their interest throughout the institute in various departments, even when these courses are not listed in the IDP program. Below is a list of some of the elective courses, this is not an exhaustive list and can be changed according to the interests of participating faculty and students.

1) **PSY775 Fundamentals of Neuropsychology/ CGS450: Cognitive Neuropsychology**

   Development and evolution of brain- Brain organization and function- Cerebral asymmetry - Neuropsychology of higher order functions- Memory language- Emotional processes- Spatial behaviour - Applied human neuropsychology.

2) **PHI 452: Philosophy of Cognitive Science**

   Functionalist Theories of the Mind; The Representational Theory of the Mind; Semantics of Mental Representations; Structure and Organization of Mind; Connectionism; The Problem of Intelligence.

3) **PHI766 Philosophy of Action/CGS451: Action and Action Control (DK)**


4) **PHI 701: Philosophy of Mind**


5) **ENG 701: Fundamental of Linguistics/CGS454: Language & Grammar** (AR, NPS)
6) **CGS455: Artificial Intelligence** (NS, HK)

Introduction- History- Uncertainty – Learning – Sensing- Action- Search, Constraint propagation and logic- language- AI and cognition

7) **CS 771/ CGS 462: Machine learning** (HK, NS, Other ML faculty in CS)


8) **PSY770/CGS 463: Bilingualism** (AR, AV)

Introduction to bilingualism – Topics in second language acquisition- Perception and comprehension in bilingualism- Topics in bilingual language production – Neurobiology of Bilingualism- Cognitive Consequences of Bilingualism – Socio linguistics of bilingualism.

9) **PSY 468: Social Cognition** (SD)

Social nature of cognition: Historical perspective; approaches to studying social cognition. Principles of social cognition: Organization, explanation, knowledge activation, shared reality, role enactment, social positions and internal audiences. Attribution: Major theories; biases in attribution; applications of attribution theory. Social schemas: Nature and types of social schemas; active construction of reality; schema development, activation and change. Social representations: Theory and issues; relationship between social representations and social schemas, Social inference: Inferential strategies and errors. Person memory: Organization of social information in memory; expectancies and memory processes; contents and contexts of person memory. Affect and Social Cognition: Social cognitive foundations of affect; reciprocity of affect and cognition; mood and stereotyping.

10) **ENG 748: Cognitive Linguistics** (AR)

The course explores language-cognition mappings in varied contexts such as unilingual, bilingual and sign language use, Crosslinguistic variations in basic conceptual domains such as time and apace and lexicalization patterns will be examined. Other topics include nature of linguistic representations open- class semantics and semantics of grammar type hierarchies and continuums
compositional structures and co-compositionality, non-compositional structures, constrains on possible grammars, perceptual processes and grounding.

11) **ENG 408: Second Language Acquisition**

The foundations of SLA- Interlanguage- Psycholinguistic aspects- Social Contexts- Acquiring knowledge for L2 use- Teaching and Second language learning.

12) **CGS 473: Introduction to Cognitive Science** (NS, HK)

Developmental Cognition –Expertise-Perception-Action-Space/Time concepts-Language-Social cognition

13) **CGS 476 : Cognitive Neuroscience** (NG, AV, DK)

This course explores the cognitive and neural processes that support attention, vision, language, motor control, navigation, and memory. It introduces basic neuroanatomy, functional imaging techniques, and behavioral measures of cognition, and discusses methods by which inferences about the brain bases of cognition are made. We consider evidence from patients with neurological diseases (Alzheimer's disease, Parkinson's disease, Huntington's disease, Balint's syndrome, amnesia, and focal lesions from stroke) and from normal human participants.

14) **PSY 499: Psychology of Language**