

Computational Neuroscience and Cognitive Systems: A Chilean Contribution to Brain-Inspired Intelligence and Socially-Aware Cognition

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ABSTRACT

Computational neuroscience and cognitive systems are central to advancing our understanding of intelligent behavior and the development of adaptive artificial agents. This paper examines the interplay between neural modeling and cognitive architectures with emphasis on Chilean research initiatives and social applications. We explore biologically inspired algorithms, cognitive simulation, and machine learning frameworks grounded in neural principles. Drawing from Latin American perspectives, we discuss how these fields can be leveraged to address challenges in education, public health, and social robotics in underrepresented regions.

Keywords: Computational Neuroscience, Cognitive Systems, Intelligent Behavior, Chilean Research, Machine Learning.

INTRODUCTION

Understanding how the brain gives rise to thought, perception, and behavior remains one of the greatest challenges in science (Friston, 2010). Computational neuroscience uses mathematical and algorithmic models to simulate neuronal mechanisms, while cognitive systems seek to reproduce higher-level functions such as learning, planning, and emotion in artificial agents.

In Chile, interdisciplinary teams in universities and national research centers are making increasing contributions to these fields (Dayan & Abbott, 2001). With support from initiatives like CONICYT and ANID, Chilean scientists are linking neuroscience and AI to solve local and global problems—from educational inequality to digital health access.

CORE PRINCIPLES OF COMPUTATIONAL NEUROSCIENCE

Modeling Neural Activity

At the neuron level, Chilean labs focus on:

Biophysical models such as Hodgkin-Huxley and Izhikevich neurons for simulating action potentials.

Plasticity models (e.g., STDP) to understand learning and memory formation.

Network simulations using SNNs to emulate cortical dynamics.

At the Universidad de Chile, the NeuroComputing Lab is applying these models to build scalable representations of the visual and auditory cortex, enabling real-time simulations of perception.

Brain Connectivity and Dynamics

Network-level research emphasizes:

Oscillatory synchronization in working memory tasks.

Graph-theoretical analysis of functional MRI and EEG data.

Multiscale modeling that bridges synaptic activity with behavioral outputs.

Collaborations with clinical partners help validate these models against patient data, especially in the context of epilepsy and cognitive impairment.

COGNITIVE SYSTEMS AND SIMULATION OF HUMAN-LIKE BEHAVIOR

Cognitive Modeling and Hybrid Frameworks

Cognitive systems simulate internal processes such as:

Perception and attention

Language comprehension and generation

Emotional inference and empathy

At Pontificia Universidad Católica, Dr. Contreras's group has developed hybrid architectures that combine neural networks with symbolic reasoning to model moral decision-making, especially in human-robot interaction contexts (CEDETi UC, 2023).

Bayesian cognitive modeling is also used to represent uncertainty and probabilistic reasoning, core aspects of human intelligence.

Social Cognition and Cultural Context

Chilean cognitive scientists emphasize embodied and social cognition, modeling how humans interact not just with environments, but with other minds (Rojas & Contreras, 2022). This has led to computational simulations of:

Theory of mind

Joint attention and cooperation

Social norm learning

These models are culturally adapted to Chilean and Latin American social dynamics, making them suitable for education and public service robotics.

APPLICATIONS AND INNOVATIONS FROM CHILE

AI for Education and Cognitive Equity

Chile faces educational disparity across urban and rural regions (Cortés & Espinoza, 2020). Computational models are used to design adaptive learning platforms that:

Adjust content based on user attention and memory performance.

Use EEG and gaze-tracking to infer engagement.

Offer feedback using cognitive fatigue prediction models.

These tools are deployed in bilingual settings and tested in public schools via partnerships with the Ministry of Education.

Neurotechnology in Public Health

Chilean hospitals and universities are using cognitive-neural modeling to support:

Stroke rehabilitation with BCIs that decode motor intention.

Anxiety and depression diagnostics via EEG and affective modeling.

Early detection of Alzheimer's through computational biomarkers derived from speech, gait, and attention data.

Tools developed under the Salud Cognitiva 2030 initiative aim to make low-cost diagnostics available in rural clinics.

Social Robotics and Human-Aware AI

At the Centro Avanzado de Tecnología para la Inclusión (CEDETi), brain-inspired algorithms drive social robots used in:

Elderly care and companionship

Autism therapy in children

Civic information interfaces

These systems use cognitive models to interpret emotions, adapt communication strategies, and respect cultural and social context.

CHALLENGES AND STRATEGIC GAPS

Infrastructure and Talent Retention

Limited access to HPC and neuroimaging equipment constrains large-scale modeling.

Brain drain persists as researchers migrate abroad due to limited postdoctoral funding and tenure-track opportunities.

Data and Integration

Scarcity of locally collected neural and behavioral datasets hinders validation.

Fragmentation among psychology, engineering, and medical research impedes transdisciplinary convergence.

Ethical Considerations

Emerging applications raise key issues:

Who owns neural data in BCI applications?

How do we model mental illness responsibly?

How do cultural values influence “acceptable” cognitive behavior in AI?

Chile’s National AI Policy provides a framework for addressing these questions, emphasizing fairness, privacy, and transparency.

FUTURE DIRECTIONS FOR CHILEAN COMPUTATIONAL NEUROSCIENCE

We recommend the following steps to accelerate progress:

Create a National Brain Simulation Hub funded by ANID, connecting cognitive labs and clinics across Chile.

Integrate indigenous knowledge systems into cognitive modeling to reflect diverse perspectives on attention, memory, and perception.

Promote interdisciplinary graduate programs across neuroscience, informatics, and education.

Invest in brain-inspired hardware research in partnership with European AI labs (e.g., ELLIS and Human Brain Project).

CONCLUSION

Chile’s growing contributions to computational neuroscience and cognitive systems reflect a promising convergence of theory, technology, and social impact. With a focus on inclusivity, context-awareness, and cognitive equity, Chilean researchers are developing models that not only simulate the brain—but respect the human realities in which those brains function.

Future research must sustain this integrative spirit, ensuring that neurotechnologies serve both scientific advancement and human dignity in the Latin American and global context.

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