# New Confabulation Neuroscience Laboratory Opens at UC San Diego

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Robert Hecht-Nielsen, Adjunct Professor, Electrical and Computer Engineering and Director, Confabulation Neuroscience Lab at Calit2

One of the nation's leading neuroscientists has established a laboratory at the University of California, San Diego to explore and expand upon a radical new theory to explain how humans think. The theory's author, Robert Hecht-Nielsen, leads the new Confabulation Neuroscience Laboratory, located at the California Institute for Telecommunications and Information Technology (Calit2) on the UCSD campus.

"Scientists still don't understand fully how brains think, despite the painstaking discovery of millions of scientific facts about the nervous system," said Hecht-Nielsen. "Confabulation Theory allows neuroscientists to wrangle with this socially significant and longstanding scientific mystery. If this theory pans out, it may also provide the technical basis for building artificial intelligence."

Hecht-Nielsen is an adjunct professor of Electrical and Computer Engineering in UCSD's Jacobs School of Engineering, and is affiliated with the university's Institute for Neural Computation. He has also been a vice president of research and development at Fair Isaac Corporation since 2002, when Fair Isaac acquired HNC Software, a company co-founded by the UCSD scientist.

With funding from the Office of Naval Research, Hecht-Nielsen and his graduate students will focus on building and exploring the operational properties of biologically realistic mathematical models of the four fundamental, functional neurophysiological elements postulated by his theory (all known to exist, but of previously unidentified function). "Our work will provide detailed predictions that experimental neuroscientists can use to guide their exploration and testing of the theory," said the scientist.

In a paper on "Cogent Confabulation" published in the journal *Neural Networks* last March, Hecht-Nielsen proposed a theory based on four key elements to account for all aspects of cognition. The first hypothesizes that the human cerebral cortex is divided into about 4,000 'modules,' each of which is responsible for describing one 'attribute' that an object of the mental universe may possess. An object attribute is described by activating the one 'symbol' that is the most apt for that object. (Each module has thousands of symbols, each represented by a collection of about 60 neurons.) "Symbols represent the stable 'terms of reference' for describing the objects of the mental universe which clearly must exist if knowledge is to be accumulated over decades," argued Hecht-Nielsen. "Past theories have avoided such 'hard' and 'discrete' terms of reference because they seem - but are not - at odds with the widely assumed 'mushy' or 'fuzzy' qualities of neuronal stimulus response."

The theory's second key element is also a hypothesis: that each item of cognitive knowledge takes the form of axonal links between pairs of symbols. These 'knowledge links,' the theory posits, are implemented using a two-stage version of the "synfire chain" structure hypothesized by Israeli neuroscientist Moshe Abeles. According to Hecht-Nielsen's theory, the average human possesses billions of these links - a claim which, if true, would make humans enormously smarter than currently believed by philosophers, psychologists, and educators.

The third foundation of Hecht-Nielsen's theory is that thinking is divided up into simple, discrete winner-take-all competitions called 'confabulations.' Each confabulation is carried out by a cortical module when it receives an externally-supplied 'thought command' input. The winner is whichever symbol of the module happens to have the highest level of excitation supplied to the symbols of the module by incoming knowledge links. "The winning symbol is the conclusion of the confabulation, and this simple confabulation operation is believed to happen in less than a tenth of a second," said Hecht-Nielsen. "It is a widely applicable, general purpose, decision-making procedure, and the theory argues that all aspects of cognition can be carried out by means of a few tens of these confabulation operations per second, many of them in parallel."

The final element of the UCSD neuroscientist's Confabulation Theory hypothesizes that every time a confabulation reaches a conclusion, a 'behavior' (a set of thought processes and/or movement processes) is instantly launched. "This explains how humans seem to launch many behaviors during each waking moment," said Hecht-Nielsen. "In other words, every conclusion reached by a confabulation represents a changed state of the mental world, and a behavioral response associated with that changed state is instantly launched." The associations between each conclusion symbol and its 'action commands' are termed 'skill knowledge,' which decays rapidly if unused because it is learned by repeated practice trials (since skill learning is managed by a deeply buried part of the brain called the basal ganglia). Cognitive knowledge, on the other hand, is long lasting because knowledge links form in response to meaningful co-occurrence of the involved symbols (an astoundingly prescient idea first advanced by Canadian neuroscientist Donald Hebb over 50 years ago).

Using these elements, explains Hecht-Nielsen, brains can apply millions of relevant knowledge items in parallel to arrive at an optimal conclusion - in less than a tenth of a second. "Confabulation is an alien kind of information processing with no analogue in today's computer science," he noted. "Tens of these confabulation operations happen in our minds every waking second, with each conclusion reached launching new behaviors, and this occurs all day long."

"Confabulation Theory argues that brains carry out cognition using confabulation as a simple, universal, information-processing operation between the brain's cerebral cortex and thalamus," said Hecht-Nielsen. "Cognition is a field dominated by bottom-up research, but our new Confabulation Neuroscience Laboratory at Calit2 aims to provide top-down guidance to researchers in neurosciences, artificial intelligence and other fields that stand to benefit if this theory pans out."

Hecht-Nielsen was a pioneer in the development of neural networks and authored the first textbook on the subject, *Neurocomputing* (1989). He has been a member of the UCSD faculty since 1986 and teaches a popular year-long graduate course on neurocomputing (ECE 270). Hecht-Nielsen is a Fellow of the IEEE and recipient of its Neural Networks Pioneer Award. He received his Ph.D. in mathematics from Arizona State University in 1974.
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