An Engineering Model of the Cognitive Mind

Carla V. M. Marques, Carlo E.T. Oliveira and Cibele Ribeiro.C.Oliveira
Instituto Tércio Pacitti de Aplicações e Pesquisa
Computacional - Universidade Federal do Rio de Janeiro
Rio de Janeiro-RJ, Brazil
{carlaveronica,carlo,cibele}@nce.ufrj.br

Abstract— Learning is a native ability of the brain. However , very little is known of the process as it happens. The engineering model presented in this works provides a base to explore the innards of cognition. The computational implementation of the model is usable to assess cognitive profiles by means of machine learning and harmonic filtering. The model relies in an evolutionary dimensional space consisting of phylogenetic, ontogenetic and microgenetic timelines. The microgenetic space reveals the state machine nature of cognition, standing as internal translator to a brain specific language. The study of this machine and its language is the key to understand cognition.

Keywords— cognition; engineering; model; language

I. Introduction

Cognition is the drive of intellectual activity in the mind. It is the pathway where data becomes information, understanding and concepts. Moreover, it is the main factor of evolution producing the homo sapiens sapiens, the very wise man. Although, whistl anatomic evolution leaves its traces, mind evolution can not be tracked directly. This leaves the study of cognition in the field of behaviorism, where the response to a stimulus is accounted as sign of mind activity. On the other hand, tracking the cognitive process is paramount to understand and optimize the thinking mind development. The best target to cognitive tracking is a model where some feedback from the actual brain process can assert the modelled internal behavior.

The actual complexity of cognitive process lays beyond any attempt to model it in fully fleshed dimensions. A feasible model must focus on a very constrained purpose in order to have tractable dimensions. This work focus on the study of the learning process, an essential aspect of cognition concerning the development of the individual and the species. An engineering model [1] is such a proposal where cognition can be reduced to a simple machine. Within the semiotics perspective of cognition, the cognitive process is an unfolding of signs against their meaning. Yielding from this concept, an automata turns out to be a suitable machine to construct a model matching the requirements of simplicity and purpose.

Computational neuropedagogy applies neuroscience to the problem of learning. In the intent to achieve this it produces instruments to assess and intervene in human learning. Intelligent games are examples of such instruments, being computer games developed through a scientific process to achieve introspection into cognitive aspects of learning. They can tap into the unconscious process of learning and interchange information between computer and human cognition.

II. The Tangibility Of Human cognition

Cognition is an internal process mostly inaccessible from the conscious mind. As Penrose [2] (2014) remarks, consciousness is a process occurring as deep as quantum events in microtubules inside brain cells.The cognition process lies down beneath brain functionality, even more deeper away from consciousness, it belongs essentially to subconscious thought. The hermetic aspect of the particular processes poses as an overwhelming obstacle impeding direct observation with accessible technology for years to come. At psychogenesis level, examination can determine intellectual improvement, once it is a process that occurs in a couple of years. Microgenesis, evolving in the short span of minutes, leaves scarce traces of its whatabouts.

The microgenetic dimension encompasses countless microprocesses that bind in a logical sequence to complete the links of understanding that pertain to human reasoning. If any of these steps are broken, access to information is interrupted

due to lack of meaning. When one speaks of microgenetics, there is a range of theories that approach the subject. Inhelder [3] is co-author of the most accepted theory, largely drawn from the extensive works of her colleague Jean Piaget. Lemos [4] increases the scope of Inhelder with modern works on this subject.

Microgenetics defines a set of states and a procedure to walk through these states using an internal encoding and processing befit to brain innards. In accordance with the microgenetic theory, the existence of these states and process arise independent of the lack of access to the current states or the mental operations. Regarding the nature and initial installation of the learning machine, it can be said that the distribution is the same for all brains. On the other hand, each brain is characterized by an individual formation process, in addition to the cultural interactions that are responsible for reformulating some areas to prevail and others to recede. As a result, the theories of microgenesis presuppose the existence of a machine common to all brains capable of stepping through all these states until the cognitive process is completed.

On the empirical side, waywardly to theory expectations, instead of a consistently staging of learning performances, what comes about is a large diversity of cognition abilities scattered among human population. Such diversity sources from the psychogenic formation and matching predisposition of brain abilities from phenotypical DNA expression.

III. Proposal of an Engineering Model

An engineering model in psychology refers to an assessment of human behaviour which presupposes that the mind-brain system is a machine. This work states the mind brain system as a language processing machine. In the neural theory of language, Feldman [5] support this approach:

> *NTL also suggests that the nature of human language and thought is heavily influenced by the neural circuitry that implements it.*

Since language is the very product of its brain circuitry, then a language processing machine is a good fit to represent the mental machine. In computing science, language processing machines are mostly implemented as an automaton. States in this machine stand for representation levels for a given chunk of language. Since the machine in study is the cognition process, this automaton goes beyond language parsing level up to the the outreaches of understanding. Ensues that linguistics must be the science to provide the basis to define each state for this automaton. Simply stated, the proposed engineering model consist of finite state machine where the each state is defined by given level of complexity of language

Linguistics being a rather philosophical science, with many niches and streams of thought, several sources must be harvested to convey a manageable computational model. Narrative thinking, Robinson [6] is a cognitive instrument that encompasses several cognitive characteristics relevant to the process of thinking. Choosing narrative as representative of an engineering cognitive model issues a simple but comprehensive spectrum. With this engineering simplification, the machine model can have a small number of states but each one being expressive enough to render the model useful.

Although the narrative model can be simple enough to build the cognitive machine, defining the relevant and consistent scope is still a extensive task. Described in an internal report, Ribeiro et al. [7] cross referenced several proposals of linguistic narrative structures with analogous structures in mathematics and science up to the point that a consistent cognitive-linguistic model emerged. This model ensues from a combination of several linguistic sources filtered to the point where each statement could have a manageable computational implementation. The resulting machine describes twelve cognitive-linguistic levels of narrative skills. As Ribeiro studies goes, narrative is just one of the possible views of cognition machine formalisation, but good enough to describe the states in a manner that scientists from diverse fields can get a grasp of it. The resulting machine is an engine representing the internal and non observable steps of cognitive knowledge acquisition, or just for short EICA. In the research to match the engineering model to the actual mental-brain cognition process, language constructs are forced back into their originating neural circuitry. To achieve this, the automaton description takes the form of a sieve, a filter that drives cognition through the machine steps, ensuing the opportunity for them to fire. Table 1 shows a sample of the sieve consolidated form linguistic narrative structure theory which constitute the core of EICA model.

TABLE I. EICA Narrative Sieve Model

EICA states	Narrative Sieve			State Description
	linguistics	complexity	lower level	
Real Object of Knowledge (ROK)	Understanding of logical prepositions.	Affective expressions.	The development of thought and language.	The ROK is the beginning of the learning process.
Paradox		Approximation from the point of view of a narrator.	The psychological development	Absence of prepositions and nexus.

Language is the hallmark of civilization, the evolutionary step that took Homo Sapiens apart of other runner up species and the tell apart feature that characterizes human high level cognition. Language acquisition is now understood as innate

human ability Chomsky[8]. Innate language acquisition is then just the ability to process language. Language processing is the process being modelled by this engineering model, and if this ability is innate, then so is the engine behind it.

IV. An inspecting machinery to analyse the cognition engine

EICA is the Engine of Internal Cognitive Acquisition, universally installed in every human brain which is responsible for the main course of cognition process. Learning is accomplished by the EICA machine, consisting of eight recognized hierarchical states ranging from simple to high complexity.

Only a cognition tracking machine can then log the acquisition process and mark the level of understanding attained. Postulating on the existence of a cognition machine, more precisely an automaton, cognitive processes evolves propositionally in a cascade of entangled and coordinated automata operations. More plainly stated, the full process of understanding develops inside the cognitive machinery as a continuous flow of intercommunicating languages across the several automata engaged in the reasoning effort Seminerio[9]. Thereafter, the whole process of accessing and acquiring a knowledge transcribes to a collection of scripts in a language circumscribed to the mental realm, unrelated to any other human language. Capturing and interpreting the internal cognition language is the key to assess the score of understanding.

Capturing vestiges of internal cognition operation enables a fine and non mediated assessing of learning, providing metrics on how to match each unique cognition with proper and adapted access to knowledge.

EICA state set is evenly distributed among even the smallest and heterogeneous population, notwithstanding the fact that it differs for each and every person, difference which must be dealt with to convey equality of understanding and universal access to information and learning.

A. Computational Cognition as intervention interface.

The development of solid cognitive models can enable a whole new aspect of the human-machine interface. The current interfaces still regard the user as a stranger. As the machine manages to synchronize with the cognitive process, the computer becomes a new prosthesis. Cognition then proceeds to inform the computer of the opportunities presented so that it presents a coherent and timely intervention.

B. Development of a research model.

Given a theoretical model of the analyzed machine, ensues the protocol required to reverse engineer the language processing mechanism. Figure 1 depicts the original theoretical machine model, based in studies of human linguistics. Named states and proposed transitions presuppose a linear progression in the interpretation of meaning.

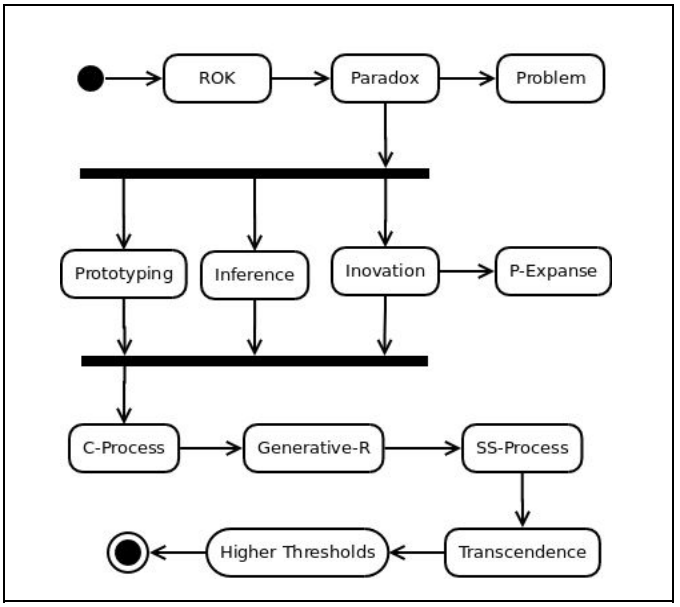

Fig. 1. EICA State Machine

Since the study purposes the investigation of the learning process, a suitable dimensional space involves three views of temporal development spans. Those dimensions recur in the learning procedures and represent evolution in three scalar ranges, namely phylogenetic, ontogenetic and microgenetic Langer[10]. Figure 2 represents a fragment of the phylogenetic dimension. Learning is represented by the human achievements in mathematics, language and science in prehistoric periods [11].

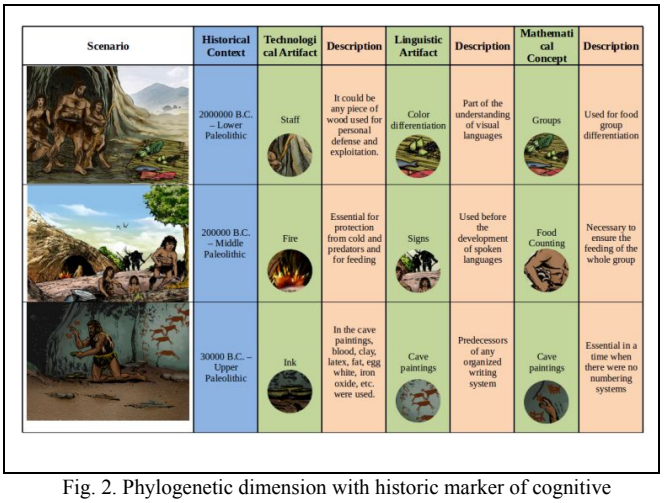

Fig. 2. Phylogenetic dimension with historic marker of cognitive

A complete dimensional model was developed to infuse the required stimuli into the learning apparatus in order to capture the full transactional profile inherent to cognitive language processing. An intelligent game was designed and calibrated to three developmental dimensions to collect vestiges from the internal cognition engine and unveil the minutia of the language processing automata.

The game (figure 3) takes the form of a scene where a paleolithic character try to make his way into the observation of the world in which he lives. Carefully designed assets conducts the caveman actions into the prospective realm of cognition, forcing advances an retrogresses in the reasoning process, coupled with the respective volitionary investigative reactions determined by the internal automata.

Fig. 3. The intelligent game for EICA

This automata, entitled to compile the incoming sensory information into cognitive knowledge have being identified in Marques (2017) [12] as the Engine of Internal Cognition Acquisition (EICA). EICA is a neurobiological computing apparatus installed ubiquitously in human brains which endows any individual with the cognition proceedings characteristic to the Homo Sapiens species. This machine is the evolutionary solution to achieve the high level of abstraction responsible for the outstanding human cognitive

C. Framework of EICA engineering

The instrumentation and observation of EICA requires a complex study and development process capable of exposing the subtle telltale traces of internal cognition machinery. The basis to the aforementioned intelligent game is the exertion of the learning process. Learning is accomplished by the EICA machine, consisting of eight recognized hierarchical states, ranging from simple to high complexity.

EICA is the essence of human learning machinery, consisting of a finite state machine in which each subsequent state correspond to a more complex cognitive achievement. Observed in EICA tracking experiments, eight recognizable states are the hallmark of the cognition automata, shown in figure 4.

Colored sections represent the states and colored arcs indicate the transitions between states. Cognitive acquisition cycles follows sensory information with volitive prospectives responses emanating from evolving or involving transitions in EICA states. The ideogram demonstrates that beyond the linear perspective of the theoretical model, transitions occurs to non adjacent states and in both forward and backward directions.

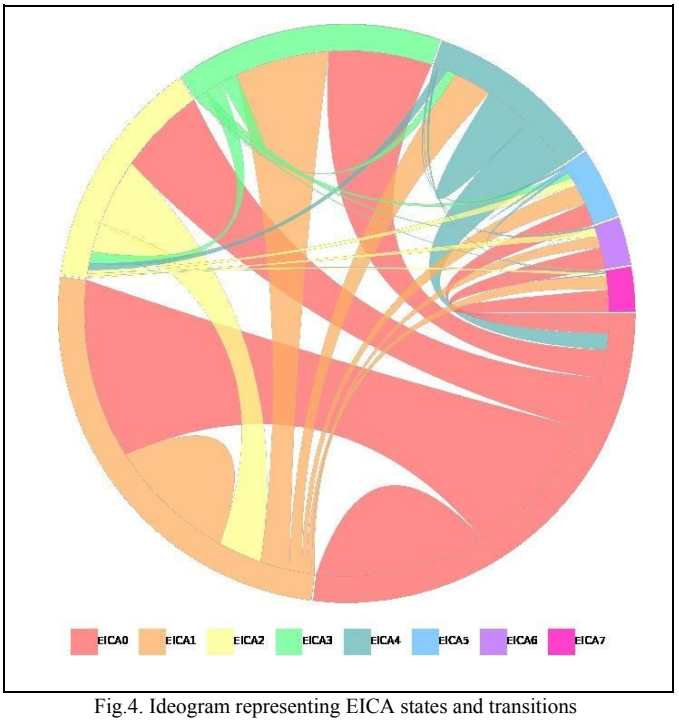

Fig.4. Ideogram representing EICA states and transitions

Ensuing transitive streams develop into concatenated expressions of meaning, imprinting the effectuated access to the given information as new linguistic nodes in the epistemic knowledge network. Although restrained to internal communication interchange among the internal cognitive structures those linguistic nodes can be observed to be the same across non related individuals. The reverse engineering necessary for that consists of inducing the volitionary response through the retrace of phylogenetic, ontogenetic and microgenetic path development. The prospecting instrument for cognitive unveillance guides the acquisition machinery into retracing the three dimensional ranges of thought development, namely the evolution of reasoning within the species, within the development of an individual and within the coalescence of an idea.

Inferably, most volitive responses that encompass a motor activity originate ultimately from transitions inside the cognitive machinery. Transitions are convulsive physical events incurring in telltale evidence, namely high order harmonics, that may propagate unintentionally through the

whole system and end up as an elusive signature of cognitive state shifting.

D. The microgenetic-paleopathic resonance

The foremost feature of this intelligent game resides in exploiting the microgenetic-paleopathic resonance to expose the innards of the learning cognitive apparatus. Encompassing the whole stream of prospective reactions, emerges a common pattern, recognizable for every and each individual. The pattern features a rhythmical response interwoven with seemingly chaotic jitter, apparently disconnected of the given information. The microgenetic-paleopathic resonance or Resonance of Marques (2017)[12] consisting of coupling between the high energy nervous motricity impulses and the faint and undetectable occurrence of transitions within the cognition machinery. A precisely calibrated analog-digital discriminator can recognize and trace (figure 5) the disturbance in the output signal caused by the originating cognitive computation of meaning orchestrated by the EICA machinery. EICA state set is evenly distributed among even the smallest and heterogeneous population, notwithstanding the fact that it differs for each an every person, difference which must be circumvented to convey equality of understanding and universal access to information and learning.

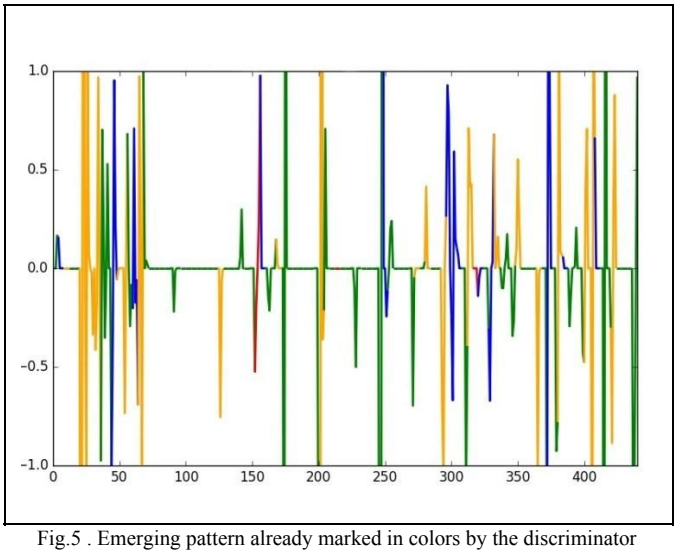

Fig.5 . Emerging pattern already marked in colors by the discriminator

E. Account on cognitive demographics

The EICA machine operation complies with a rather strict deterministic behavior which is the same in every individual observed in the available experiments. The temporal distribution of states and transitions are rather logic and regular across the sampled population (figure 6).

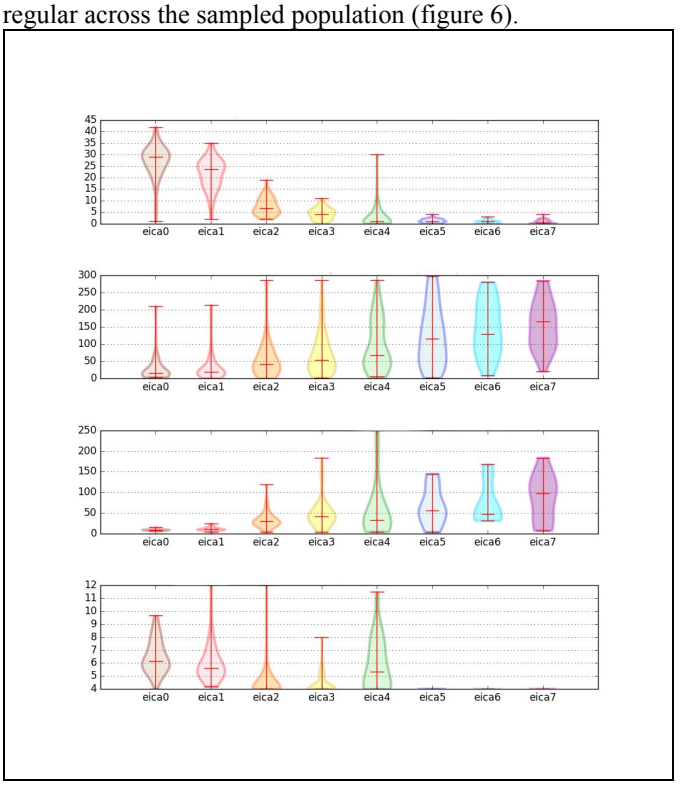

Fig. 6. Violin distribution of EICA state characterization

Equity in EICA machine configuration among the human population implies, from the cognitive point of view, that all individuals have the same aptitude to learn, therefore deserving equal and universal access to knowledge and understanding. Uniqueness in individual experience and education results in a idiosyncratic usage of EICA machinery, departing each person from the expected EICA behavior. Those unique usage patterns are kindred to personality formation and may not imply in a better or worse cognitive performance (figure 7).

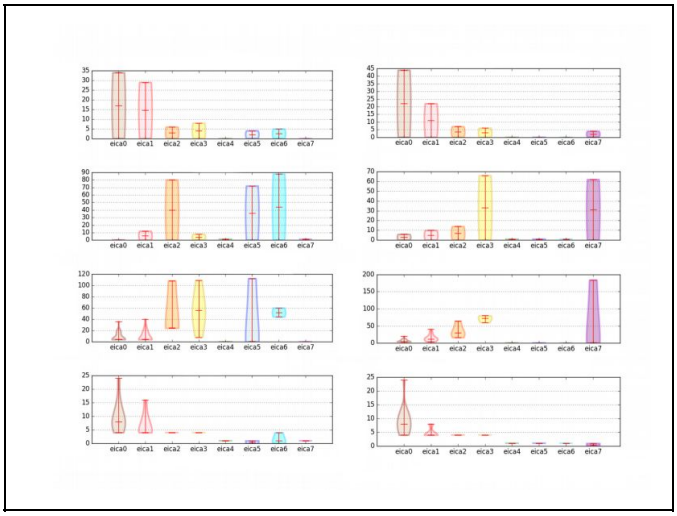

Fig.7. Statistic variations of EICA state events

Universality and individuality are both inherent to EICA machine manifestation in human population. Universality express itself as a recognizable consonance of operation and as well as commonalities in the reasoning stream development.

Individuality concerns to variations in states and transitional sequences defining a peculiar traversal of cognitive acquisition landscape singularizing a personality driven behavior. Similarities in the diverse meaning construction narratives demonstrates that all cognition processes converge to a prototypical epistemic subject quiescent in every person whilst particularities alert to an adaptive conformance requirement for accessible knowledge outspreading. The personal idiomatic nature of cognition inflow requires the assessment and compensation of those differences hitherto taken for granted in education, eventually hindering the establishment of a universal access to knowledge.

F. Demographic cognomics

Cognition is the mechanism by which all learning, reasoning and reflection on any knowledge is realized. Also therein lies every obstacle to understanding when some cognitive mechanism or procedure is not perfectly functional. Understanding cognition is a crucial path for fair and equitable access to knowledge and understanding of the world around us.

The inference that cognition machinery is equally available to every person is the principle behind the proposition of an effective universal access to knowledge. Monitoring the EICA machine performance is a mean to assess and even adapt the process of learning. Under the universal access principle, this means that beyond all the differences that uniquely identify each individual, everyone can have access to knowledge through intelligent systems.

The computer will go from a luxury accessory to an effective and powerful instrument in the hands of teachers, making their work more productive and less frustrating.

The temporal space considers the models according to the sampling time granularity of cognitive development . This space delimits research strategies that are mainly focused on the individual. This space should prioritize the diversity of intelligences and highlight individual differences as the essential patrimony of humanity.

Populational space portrays the variation of cognition among individuals in a population. This study should delimit favorable and unfavorable variations. The favorable ones offer a differential to the individual that qualifies him to a relevant social position. The unfavorable ones can mean failures in the individual cognitive apparatus and must be analyzed and corrected. Cognitive models must be parameterized so that they can preserve the diversity of the population, ensuring that all necessary skills are nurtured in education.

The diversity of intelligences is the main legacy that must be preserved in the human species. Education must be rethought so that individual differences are taken into account. Cognitive models should be developed with this variability in mind. They will be the facilitators of the personalization of the educational process, preventing the mass process from misrepresenting the purpose of bringing everyone to full development.

Within the diversity of the cognoma in a population it is possible that characteristic groups emerge. The identification of these groups is part of the population study. These groups can be used to improve understanding of the cognoma, noting the differences between them.

Both differences and similarities are important points in cognitive modeling. Differences mark the limits of cognitive distribution in a population. The similarities are markers of cognitive specializations that must be considered in both the modeling and the teaching process, which must take into account these peculiarities. Monitoring eica machine performance is a mean to assess and even adapt the process of learning.

Understanding both the universality and nonuniversality of cognition process assures that learning is accessible to any human being at any level. The inference that cognition machinery is equally available to every person is the principle sustaining the proposition for an effective universal access. However, unique and personalized use case profile of EICA states provides both for essential diversity and complexity for effective and efficient learning. Monitoring EICA machine

performance is a mean to assess and even adapt the process of learning.

V. Conclusion

The actual report for EICA model is a collection of lecture notes spanning ten years of Computational Neuropedagogy Post-Graduate course, each year focusing in a specific area of the concerning research. Hundreds of students produced thousands of pages to accomplish this elegant and comprehensive model. Glimpses of EICA can be observed out of simple tabletop wooden games, but are much less consistent than needed to comply with the rigors of science. Nevertheless those observations were good enough to guide the path of science towards a better understanding of the innards of cognition.

EICA model is an instrument of neuropedagogical science, devised to understand failure of learning and guide solutions to this problem. It is the result of systematic study of several relevant authors in cognitive science. EICA comes true by abandoning attempts of reaching to the actual complexity of the mind in favor of an engineering solution that can produce coarse but useful results. As much simplistic it can seems from computational science, EICA has shown the potential of understanding both individual and populational cognitive features. Statistical coherence of the model is reassuring of its potential not only for the study of human learning process but also for other related fields like ergonometrics and high performance requirements.

From what can be learned from this work, this model just opened a small peephole into the vast field of computational cognitive science. The great challenge opened is what can be named as cognomics, the study of the complete set of languages and cognitive language expressions that comprises the inventory of the thinking process and the corresponding epistemics, the effective knowledge that emerge from the given cognitive microgenetic scripts. This can open the path for a better humanity where cognition can be evenly distributed and every person can experience the benesses of being a fully developed Homo Sapiens.

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