Cognitive Topology Mapping based on Human - Computer Interaction

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Abstract

The system point of view, the human-computer interaction (HCI) structure is composed of "brain cognitive body - coupling situation - information manifold" cognitive digital system. HCI process coupled interaction between brain cognition and brain outside the information system, the formation of cognitive coupled states. The Outside brain cognition point of view, the situations of HCI is the point of the link between the brain cognition and brain outside information manifold, the cognitive been induced brain outside the cognitive digital manifold. The Outside brain cognitive information measuring point of view, BSM is a brain cognitive observation, mapping, research platform. The cognitive topology layer is system kernel. We tried to use the coupling cognitive research framework in a word memory. Assuming the brain state of English word to the existence of complex networks, explore the network activity model of word. The coupling method is based on BSM online research of models, acquisition of cognitive symbol sequence data of learning word; The formation of the word topology base on word classification specification, definition of the word linear metric space, form the basis and platform on Complex word network of static structure and dynamic growth. Preliminary results of this study confirmed that Cognitive coupling is feasible way to Brain imaging of cognitive information.

1. Introduction

Observing brain cognitive activities, acquisition of cognitive data, to establish the cognitive structure model, cognitive dynamic system, Explore brain cognitive secret is an important goal of the science of this century. Comparison to the vast universe and the tiny atom still in the initial stages of the study of the human brain cognitive. What factors hindered our exploration of the brain universe? We believe that this factor is a research tool, the paradigm that needs to build tools such as telescopes, microscopes, particle accelerators.

2. Man-machine Separation Functional Simulation

Information processing mechanisms of the human brain can not be detected directly from the external, Anatomic methods can not be directly observed psychological microscopic processes too，So, we can only simulate the brain using a computer, with the help of theoretical thinking to do indirect reasoning for brain activity and the mechanism, as “black box” method. This is the implicit assumption of 50 years of cognitive science，Research paradigm called “man-machine separation functional simulation”. Functional simulation can not be collected brain cognitive activities continuous data. It is difficult to construct a quantitative cognitive model.

Cognitive perspective, the brain - machine is closely integrated in the human-computer interaction environment, We can see the computer as the observations, the modulation of brain cognitive tools, Computer bombards brain cognitive and continuous acquisition process data, build the brain universe model [1].

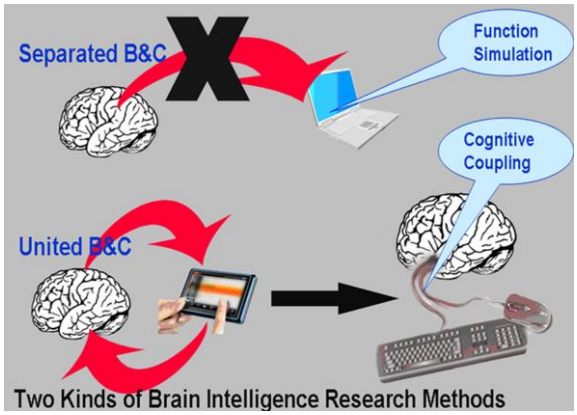

Figure 1. Two kinds of artificial intelligence research methods: Functional simulation, Cognitive coupling. Currently, most artificial Intelligence research methods are the functional model. Cognitive coupling stress online, situated.

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2.1. Outside Brain Cognitive

Insight into the paradigm of the "man-machine fusion structure" observations, based on the philosophy of the complementary principle， That direct observations, collecting the brain cognitive content data, explore the brain universe structure and motion law. This method is possible? Bold idea: the brain cognitive induced skull external environment observation， The cognition can exist outside the brain? We should go to understand the cognitive philosophy frontier[5].

- Situation cognition: The development of cognition, knowledge and intelligence is rooted in the agent - environment interactions, mutual adjustment and adaptation. The cognition is thea overall event that agent - environment interaction and the relationship. Environment is not simply the cognitive object in epistemology, it also supports the survival of the agent. Cognition for survival, it is pointing to the environmental activities.
- Distributed cognition: Hutchings published in 1995 a representative work "Cognition in the wild" proposition: the cognitive activity, and distribution to others, the technology of artificial objects, external representation and the environment together constitute the cognitive environment, cognition is distributed phenomenon.
- Extended cognition: Extend cognition and extend mind caused international shock and controversial philosophy of the cognitive hypothesis. This hypothesis was proposed by Clark in 1998[6], advocated: the mind can be extend outward, into the series cognition objects such as tools, media and others, Agent can be extended to the brain outside the tool.

Comprehensive contemporary cognition forefront of philosophical concepts, we believe that: the cognition can be exceeded skull boundaries, activity in outside brain. Agent is coupled or induced to the brain external environment by the situation, referred to as "coupling cognition".

2.2. Digital Learning on HCI

This is the era of information technology widely infiltrated. The world of information based on human-computer interaction is to become the basis for human survival environment. Digital world and cognitive world is full integration, which means we are able to affect cognitive world by shaping the digital world.

To obtain the status word memory in the brain learners, the data collection process of learning is the key. We view the study of cognitive brain, higher cognitive brain research with offline and online in two ways. Online research in human-computer environment as the basic background, data acquisition and cognitive control in online environments. And brain matter and energy level comparative study, Cognitive coupling is acquiring, brain cognitive-online data [1,12].

3. BSM-based Cognitive Observations

The system point of view, the human-computer interaction (HCI) structure is composed of "brain cognitive body - coupling situation - information manifold" cognitive digital system; The information point of view, HCI process is coupled interaction between brain cognition and brain outside the information system, the formation of cognitive coupled states; The Outside brain cognition point of view, the situations of HCI is the point of the link between the brain cognition and brain outside information manifold, the cognitive been induced brain outside the cognitive digital manifold; The Outside brain cognitive information measuring point of view, BSM is a the brain cognitive observation, mapping, research platform.

3.1 HCI-based Cognitive Digital Manifold

When online collection of information during cognitive brain, we should be given background information space structure of cognitive, In mathematics called manifolds. In Einstein's general theory of relativity, gravitational field space-time is Riemannian manifold, space-time is curved, and each local area is flat, and to describe with Euler space frame.

Many mathematical concepts introduced to psychological research by Piaget, and he done a lot of pioneering work. The morphism and category application in the development of cognitive systems analysis[11].Build cognitive-logic digital environment, digital systems and cognitive is morphism, and produce cognitive assimilation, conform and balanced. Acquisition coupling process cognitive information, to be obtained the cognitive logic fine details, looking to morphism exist in digital systems, to study the cognitive dynamics system in digital systems[1].

Cognitive perspective, HCI is the "Brain Cognition body - coupling situations - information manifold" (BSM) composed of digitizing understanding system outside the brain.

Definition 1 Coupling Situation: The boundary of the brain cognitive body is the skull. It is a the

brain cognitive physiological carrier, is also the basis of individual smart material.

Definition 2 Brain Cognitive Body: The boundary of coupling situation is to be the brain perceived the object, including the situation man-machine interface, the intelligent device interaction situation and the local objective environment.

Definition 3 Information Manifold: The information manifold is a digital information system, and interconnected with human-computer scenarios interface, intelligent devices. Its borders are smart devices, and information network systems, including man-machine interface, and its extension is connected to the sensor.

We hope to build a visualization BSM digital dynamic system. It similar to the cosmology of the cloud chamber which is filled with clean air and alcohol (or ether) saturated steam. If broke an invisible charged particles, it becomes "cloud" condensation of the core to form a cloud point, and these fog point would show the "footprint" of the particle movement. Similarly, we hope that the BSM vector system can become the agent activities "cloud chamber".

3.2. Cognitive Coupling States

Based on our study the brain at the information level, we need to study the brain information processing active, and choose apparatus with the brain is coupled to the processing of information, collection of data the brain activities and online, rather than material or energy, so that recorded data will reflect the secrets of the brain information processing, and temporarily do not study the brain state of matter and energy, only to focus on brain information processing itself, is undoubtedly the computer is the best choice. The brain base on the information level known as "Information Brain "(iBrain)[1].

When the brain operate a computer, the computer software system related operations on the brain to respond, for example, records of cognitive operation, determine the next logical step in accordance with relevant cognitive operations, that is, between the brain and the computer constitute the output of each input to achieve information coupled state.

Definition 5 Cognitive Coupling States: It contain that 1) the researchers on cognitive content, logic, rules, procedures, track design, 2) also includes the brain to understand the cognitive situation design of researchers , 3) and after understanding the brain's response to these situation,4) computer decisions next node to operation based on the reaction process brain, achieve cognitive modulation,5) If the brain acts in accordance with the preset orbit activities, means that the designer's cognitive assumptions is match to subjects cognitive, related cognitive rules is verified, 6) Otherwise, either cognitive law to be amended, or is the need to improve cognitive modulation, or other reasons[1].

The object, content, rules of cognitive operations and procedures, track and other, sum referred to as Cognitive Information Space(CIS). Purpose of the introduction of CIS is to design software, so that the brain information space "materialized". Cognitive researchers can use software, and study with the Agent that mapping the brain behavior into CIS. It is similar to the electromagnetic field, Agent like electronics [1].

Definition 4 Cognitive Coupling Digital Manifold: Outside the brain cognitive concept, coupling cognitive-based man-machine interactive environment, Agent technology, the cognitive projection information manifold and Cognitive processes in this manifold imaging. Called manifold as Cognitive Coupling Digital Manifold (CCDM), or Cognitive Digital Manifold (CDM). We hope the CMD is cognitive cloud chamber observations.

3.3. Cognitive Atlas

Atlas is an important tool for analysis of BSM structure. Cognitive manifold atlas of the following:

- Tree Atlas: The tree is cognitive manifold common atlas, for example, the tree of knowledge, the concept of tree, the directory tree, data tree and so on.
- Network Atlas: Vertices of the network represents the point on the cognitive manifold; edge represents the relationship between cognitive manifold points.
- Table Atlas: Cognitive object to be compared regularly arranged, easy to understand.
- Other ways Atlas: Chain processes, and so on.

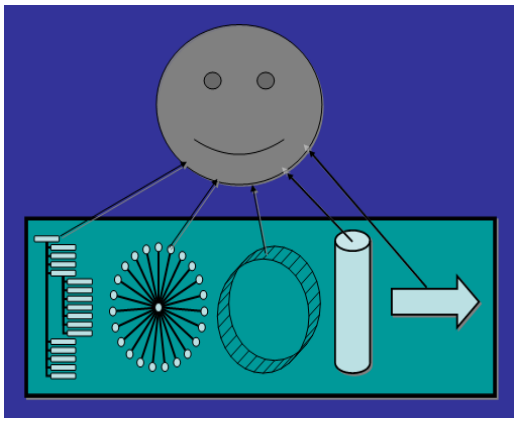

Figure 2. Cognitive manifold Atlas

3.4. COM Frame

The situation can use the three dimensions of the content, operation, mathematical description. Content, operation, mathematical referred to as the basic frame of the situation:

- Content: Situation inherent in the cognitive object element.
- Operation: The situation includes cognitive operations, logic, processes.
- Mathematical: Context contains the mathematical dynamic system properties.

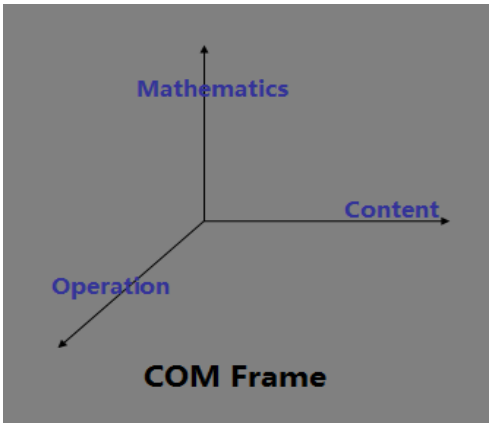

Figure 3. COM Frame, cognitive manifold base frame.

Situational content, operation, mathematical frame is also named for the COM Frame. Cognitive frames are varied, different situations is available in different frame expression, but also reflect the cognitive personality; Local cognitive manifold to achieve associated with the cognitive frame; The frame is a fine expression of cognitive manifold local, in-depth explanation or more layers of abstraction, a detailed description.

4. Cognitive Topological Mapping

Based on the above cognitive coupling concept, to create object, topology, manifold, logic, coupled cognitive digital manifold mathematical system. The cognitive topology layer is system kernel.

The cognitive topology is a graph homomorphisms with add additional structure in cognitive object collection. For example, based on the situations information flow system, additional cognitive logic[7]. Cognitive topology based on BSM, we were able to apply computer visualization technology, cognitive collection object abstraction point feature, the relationship between cognitive object abstraction for the line, plus additional cognitive logical constraints to form a visual diagram. Based on the graph homomorphisms operation between brain cognition and information manifolds, to achieve the imaging of brain cognitive information.

4.1. Complex Networks

1)Manifold diagram approximation, or, in a certain perspective isomorphism.2) Graph G = (V, E) contains two sets: V is the set of vertices, E is the set of edges. 3)For sampling from d-dimensional manifold, the sample data set x, the first to establish one-to-one correspondence between the data points and the vertices of a graph G, and define the similarity of pairs of data points for the edges in the graph, so according to the data points to establish a homomorphism chart.4) Graph and the manifold, there are many similar properties, the most important point is that can be embedded in the Euclid space. 5)A homomorphism graph is a topological manifold objects. the performance of its topological properties of the edge weight. 6)We use complex cognitive networks to describe cognitive manifold network node represents a cognitive object. Atlas is a subset of the complex network, the frame is multi-dimensional cognitive object decomposition.

Over the past decade, complex networks are placing high hopes to become a tool to describe complex systems and methods, means, a tool for studying complex systems[8,9,10]. We believe that the BSM cognitive manifold can be isomorphic to the complex network. Complex cognitive networks can become a carrier that Agent brain outside the presence and activities.

Manifold perspective, the complex network is a carrier and tools with cognitive manifold of dimension reduction.This is an important step of the situational vector that BSM high-dimensional cognitive manifold projection to the complex network.

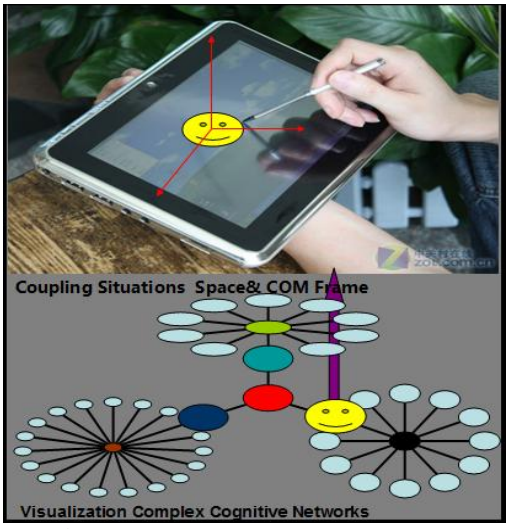

Figure 4. The situation can measure complex cognitive network of local

4.2. Cognitive Measure base on Situation

In mathematics, a manifold locally isomorphic to the European space metric. Measure is an important method of research, observations cognitive manifold structure, but how to measure cognitive manifold? We believe that coupling situation is partial characterization of cognitive manifold, contains rich cognitive information. Cognitive situations is a high-dimensional manifold , needs dimensionality reduction.

Innovation COM-based cognitive frame situations vectorization method, cognitive space deployment cognitive operations feelings, gathering the cognitive operational information to achieve cognitive manifold dimensionality reduction and observation.

Figure 5. Based COM frame language learning vector situations: The circle is a cognitive sense, be deployed in the top of the learning object. For example, when the computer issue [wud] sound, students should click on the cognitive object wood.

5. System Architecture

When online collection of information during cognitive brain, we should be given background information space structure of cognitive, the brain structure of the word information space. According to the language of science, the basis of complex networks. We assume that the word of the information space of brain is a complex network topology model, Word cognitive activity in complex word network. We're trying to get the word cognitive network specific topology with coupling, get the word complex network of brain activity patterns.

5.1. Complex Word Network Topology Space

The English word set to memory, such as the 6000 English word, abstract for the topology according to a classification. Let W be a set of words, W a subset of the family τ is called a topology of W, if it satisfies [2]:

1.W and the Ø belong to τ.

2.τ in any number of members and is still set in τ.

3.τ in the intersection of finitely many members are still in τ.

τ of words set of meet the above three topology axioms is a word topological space, denoted by (W, τ). We call to word classification specification form W as a subset family or word topological space. Depending on the classification specification W word set can have different topologies or space. For example, the formation of word meaning network topological spaces according to the word semantic regulate; In accordance with the letters A-Z word order rules ,word can be divided into tree topological. Tree and the network topology is commonly used words.

The establishment of trees and network linear matrix space[3], to achieve the mathematical study of the word topology; In order to facilitate the mathematical calculation, define two measures: the amount of relation(R) and long distance(L) between word.

1.R: In the topology of word x and y are directly connected to R = 1,If not associated, or association with their own then R=0.

2.L: In the topology of word x and y are directly connected to L = 1,If not associated, or association with their own then L=0.

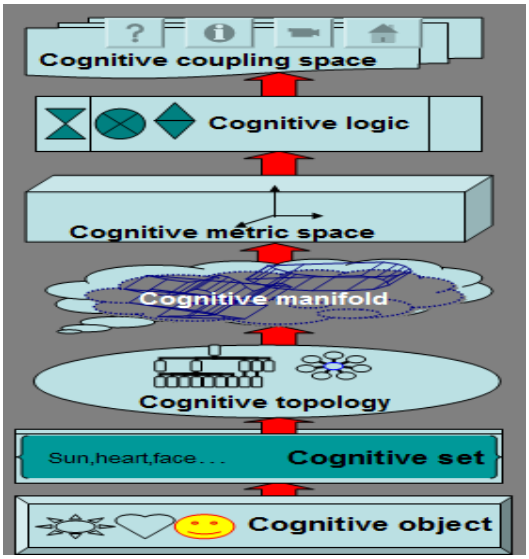

Figure 6. Word cognitive architecture: set of word—> Topology of word—> Word metric space—> Cognitive Logic — >Cognitive coupling space Schematic diagram.

R and S can be verified to meet the definition of measurement:

Let X be a set, ρ: X × X → R. If for any x, y, z ∈ X, exist:

(1) (positive definiteness) ρ (x, y) ≧ 0, and ρ (x, y) = 0 if and only if x = y;

(2) (symmetry) ρ (x, y) = ρ (y, x);

(3) (triangle inequality) ρ (x, z) ≦ ρ (x, y) + ρ (y, z),Claimed that ρ is a measure of the set X. (X, ρ) is a metric space.

With the word topology measure R, L, linear space, combination of cognitive, equations, matrix tool, achieve word cognition network dynamics.

Based on different word cognition method, We build complex word network topologies to form the initial Information network space of word in the brain. It is base for imaging of brain activity for the word cognition, and obtain the fine structure of word cognition network topology[4].

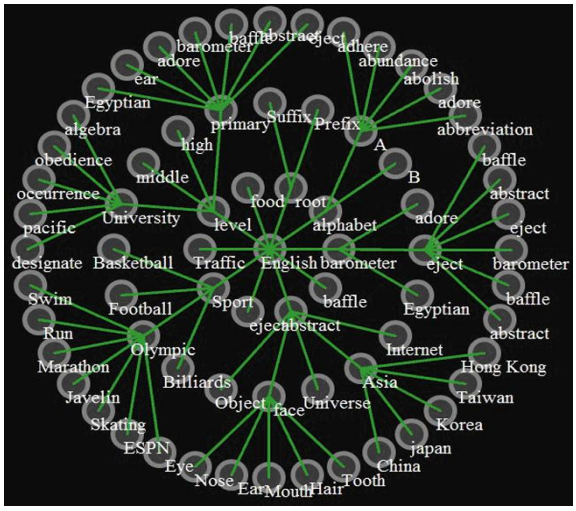

Figure 7. Word cognitive brain imaging network film: According to some rules, word set abstract of the network topology, similar ,the film to camera Cognitive activity of the brain, photographic process of the brain word memory Learning.

5.2. Man-machine Interface of Cognitive Coupling

Man-machine interface of cognitive coupling is based on software technology, deployed in human-computer interface cognitive space. By the cognitive schemata, sensory points, effectors , cognitive symbol sequence acquisition, control base etc.

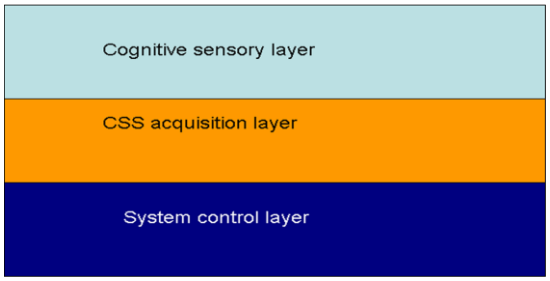

Figure 8. The spatial structure of cognitive coupling: Build cognitive scene layer on the man-machine interface, deployment of cognitive operations collection point, record cognitive operation and to achieve control and transmission.

Needs to grasp the two core points based on cognitive coupling states research, the cognitive coupling states modulation and the cognitive symbol sequence（CSS） acquisition. There are a variety of man-machine interface cognitive operation acquisition mode, what we need is a record for the cognitive dimension, for example, In English the word dictation process ,we are given a text box, as word dictation box operation ,we can have the following recording: 1） Just record the results of dictation, That learners correctly spell the target word, represented by 1 0 dictation correct errors;2) The process of recording keystrokes of learners, such as B-U-K-O-O;3)Record cognitive symbol sequence , such as, book_b-b-bl-b+bo-boo-book;book_b-bo-box-bo-bb-bo-boo-book;book_b-bo-box-bo-b-bu-bux-bu-b-bo-boo-boox-boo-bo-b+;book_b-bo-bok-bo-boc-bo-bb-bo-bog-bo-bd-do-dog-do-db-bo-boo+book; book_b-bo-boc-bocj-boc-bock-bck-buck-bck-back-bck-bock-bck-beck-bec+be-bb-be-bec-beck-bck-bick-bck-beck-beack-beck-bck-bc-boc-boce-boc-bo-b.

5.3. Cognitive Coupling Space and CSS Processor

Processing cognitive Symbol sequence data is to achieve the reconstruction of cognitive processes or characteristics of the associated. Based on the basic measure R and L of metric space, select the appropriate coordinate system form to build computing model, additional metric space node a new cognitive structure upgraded to cognitive coupling space, such as vector V, virtual connection I, the transfer matrix M, operator, etc.:

1.(Vector) V: Cognitive metric space node is attached cognitive orientation form a cognitive vector.

2.(virtual connection) i: Cognitive metric space node is attached virtual channel connections between nodes.

3.(transfer matrix)M: Cognitive metric space node is attached transition matrix of cognitive operations.

4.(operator) operator: Cognitive metric space additional other operators to build field, potential, curl, divergence and other additional metrics and complex structures.

5.Cognitive mathematical equation: Based on the above structure, shows cognitive coupling dynamic equations, build cognitive coupling dynamical systems.

Processing CSS, difficulty is to be restored to the one-dimensional CSS data to high-dimensional cognitive space, to find mathematical tools for L-dimensional and dimensionality reduction.

5.4 Cognitive Coupling Modulator

Base to the word topology, metric space and cognitive coupling space, we build Cognitive Coupling Modulator, according to individual characteristics, dynamic constraints on cognitive processes of cognitive dynamic coupling space, modulation of cognitive coupling states, individual cognitive processes to achieve the scientific control, improve the cognitive efficiency.

Cognitive modulation of the word network, suppose the word growth is a complicated process network growth model, based on a complex network of research tools and methods for modulating the growth of word recognition [4].

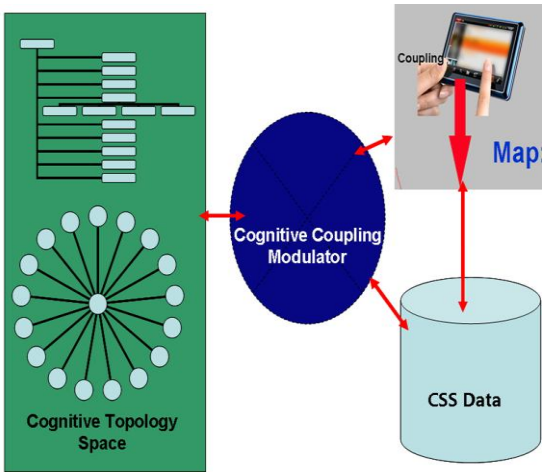

Figure 9. Complex word network model: Base on word network topology, metric space, acquisition of CSS data, achieve to personality analysis, build cognitive coupling space, modulation of the human operation to cognitive coupling states.

6. Preliminary Results

Based on the above research ideas, we collected data on more than 1000 junior high school students, Get the following preliminary results.

6.1. Chinese Students Confuse the Letters A-Z map

Acquisition of more than 200,000 the CSS of China students in English word dictation, find the record of word first letter misheard, get to Chinese students confuse the letters A-Z map, found the confuse duality between A-Z.

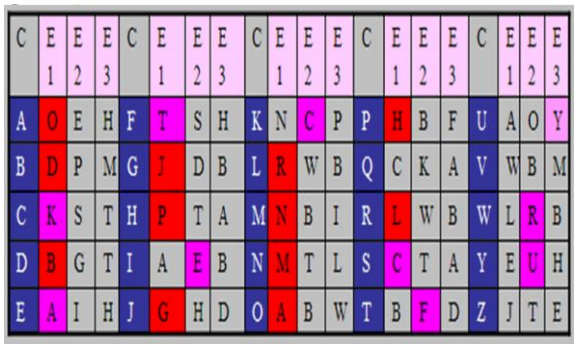

Figure 10. Confuse map of the letters A-Z: This table reflects how students A-Z of confusion between, Such as ,listen to the letters A to O,E, H(sorted according to the percentage of errors), and found the rule, the error word to mutual authentication, for example, A hearing for the O, on the contrary, O is also confusing for the A. X is no validation of data. So, The sequence analysis of the use of cognitive symbols, reflecting the process of Chinese students the dynamic characteristics of listening. Currently only a simple analysis of these cognitive sequence data, next, the middle character error will be analysis, and build sophisticated dynamic model of Chinese students of English listening[1].

6.2. Cognitive Coupling Brain Mapping of Complex Word Network

Based on the Figure 3, we worked out network topology photographic film, to obtain a status of individual words in memory.

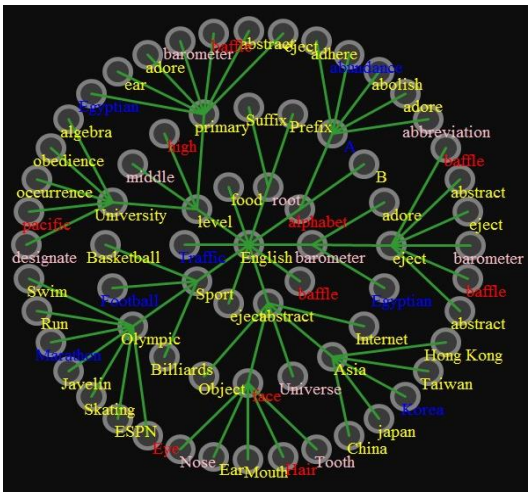

Figure 11. State diagram of the memory word: Red is extremely difficult to remember, Pink is difficult to remember that, Blue fuzzy memory, Yellow means easy to remember.

7. Conclusion

1) The "brain cognitive body- coupling situation - information manifold"(BSM) is composed to cognitive digital manifold research platform base on cognitive coupling states.

2) Coupling situations is induced, link the brain internal and external cognitive manifold node, also a local measurement of cognitive manifold.

3) Base on COM cognitive frame to establish vector situations space for achieving cognitive metrics.

4) To collect Cognitive symbol sequence, high-dimensional cognitive manifold homomorphic to complex cognitive network of low-dimensional manifolds, to realize cognitive topology mapping.

5) Use this method in the English word memory and learning behavior, collection data with smart devices, access to cognitive processes information that is difficult to obtain on traditional psychology with topology mathematical tools for data processing.

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