Cognition & Innovation: Roles of Cognitive Neuroscience in Fostering Awareness of Innovation in Manufacture Industry

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ABSTRACT

This paper explores what is the role the Cognitive Neuroscience plays in cultivating manufacture innovation consciousness. Under a CN model as built here, we analyze the CN about its impact on manufacturing innovation and introduce data about it in China's manufacture industry in attempt to make an empirical study on it. Study finds that as this academic level has advanced up to a new high record, it has exerted a significant catalytic effect on manufacture innovation capacity, especially on high-tech-intensive industries. More of that, foreign direct investment, tangible capital accumulation, workers' education levels and investment in R&D also contribute much to the improvement of innovation capabilities.

Key Words: Cognitive Neuroscience, Manufacture Industry, Awareness of Innovation

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Introduction

Manufacturing industry is the mainstay of the national economy in China. Today, China has accelerated the pace of building a national and provincial innovation center in the manufacturing industry. Maybe this is an important opportunity for China to integrate the national manufacturing industry into the "national team", transform the science and educational advantages into industrial strength, manpower into talents, and industrial energy into built-in-quality. The manufacture innovation center focuses on developing cutting-edge and common key technologies for R&D supply, transfer-proliferation, and initial commercialization as three dimensions jointly composed of a seamless chain that forms the industry. To lay a solid foundation for the development of manufacture industry, a realistic choice we have to face is to make a good job in building the manufacturing innovation center. With the advancement of life sciences such as genes, brain nerves, and cognition, intelligent science is gradually unveiling its mysterious veil and becomes the motive force of basic science in the 21st century. In the field of modern manufacture information technology, many intelligent technologies have sprung up and found widespread applications in all walks of life, such as, language recognition and comprehension, image recognition and treatment, computer vision, robot plan, multi-information sensing and control, knowledge representation, acquisition and processing, reasoning and decision, expert system, intelligent optimization control, etc. (Catozzella and Vivarelli, 2014). The human brain has many functions. From a CN perspective, the reason why human can grow into the lord of all the souls is that the neocortex in the human brain is large enough and expands sharply, while the primary mission of

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it is to store the information, in other words, our innovations are stored in the neocortex after encoding. There was no significant change in the bone cortex and mesothelium from the earliest rodents to the current primates. We believe that human intelligence may be attributed to the leap from the quantitative to qualitative change in our innovations (Xu *et al.*, 2011). Therefore, we hope this model may be applied to the cultivation of manufacture innovation awareness. The whole CN system has two major branches: microscopic neural circuits and macroscopic artificial intelligence. The study coverage of CN is shown in Figure 1. From the perspective of CN, this paper attempts to use the basic results from studies on this subject to reveal the more abundant details of cognitive processing in the cognitive theory model for manufacture innovation. The investigation and practices are thereby constructed on a more solid science foundation.

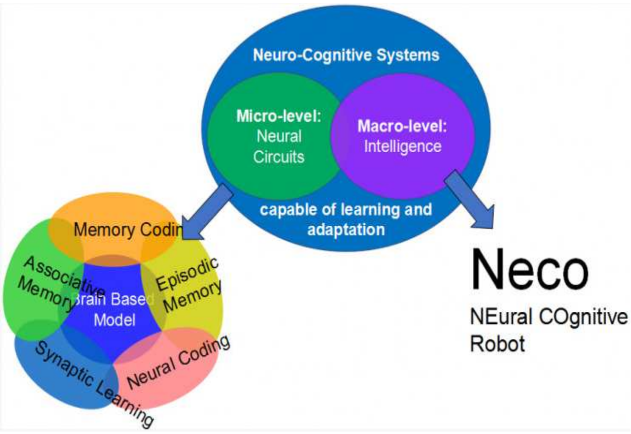

Figure 1. The research content of neurocognition

Analysis on the innovation theory of neurocognitive science and manufacturing industry

The basic point of view of neurocognitive science

The CN takes psychology interpretation, especially the brain mechanism of mental activities, as its own missions. It mainly studies humans and other high-grade primates, as well as other lower animals (Lin and Li, 2011) based on two philosophies. The brain has multiple layers in structure. The results from a survey conducted on the neurocognitive strategy are shown in Table 1. Take human as an example, the human brain is an open complex mega system. As a highly organized organ consisting of about 100 billion neurons, it includes some different types of neurons and neuron groups, neurochemical substances, neural pathways and networks, and diverse neural electrical activities, all of which are not disorganized, but done with a distinctly diversified multilayer structure (Glynn *et al.*, 2010).

Table 1. Survey results of neurocognitive strategies

	Always use	Usually used	General use	Usually do not use
Cognitive strategy		56%	44%	
Metacognitive strategy		45%	49%	6%
Emotional strategy	16%	68%	16%	
Communication strategy		65	35%	

In the first layer, there are the bioactivity molecules, including various neurotransmitters and neuromodulators which have reached more than 100 types as discovered by far, and receptors that specifically bind to transmitters. Most importantly, there are acetylcholine, dopamine, and serotonin, etc. These molecules constitute subcellular structures such as synapses, dendrites, axons, and so on, each of them then forms a neuron as the basic unit of the brain. The neurons further make up a simple local neural network, such as a cortical functional column (Berzin *et al.*, 2014). Local networks form encephalic regions that can finish certain functional activities, such as the amygdala and hippocampus, etc. Multiple encephalic regions can develop function systems, including visual systems and auditory systems, etc. The human brain is then composed of multiple function systems. The structure of each layer is a system formed by the next layer structure as a unit and has functions that the next layer structure does not have (Liang *et al.*, 2013). This multilayer structure in the brain determines the multiple layers of brain functions, for example, from the peripheral nerves to the lower center, the subcortical center, and to the upper center, from sensation to perception, innovation, thinking, etc., all of these are the reflection of this functional layers. The traditional cognitive processing model is proposed as follows Figure 2:

The structure of the brain underlies encephalic functions, but there is no simple correspondence between structure and function. The CN aims to reveal the relationship between psychology and cerebrum, in fact, that is the relationship between function and structure. In this regard, the idea that predominates anything before the CN emerged as a discipline is the "theory of functional localization on cortex.

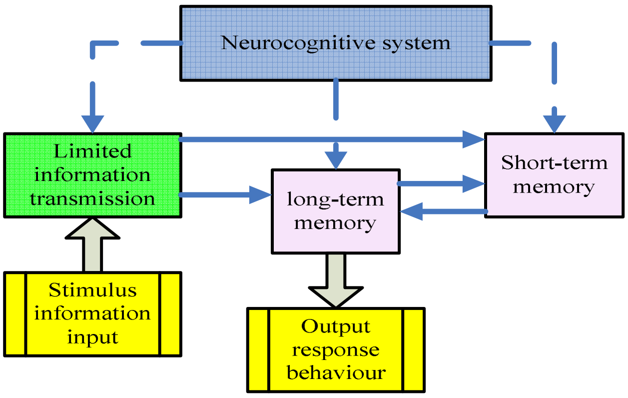

Figure 2. Traditional cognitive processing model

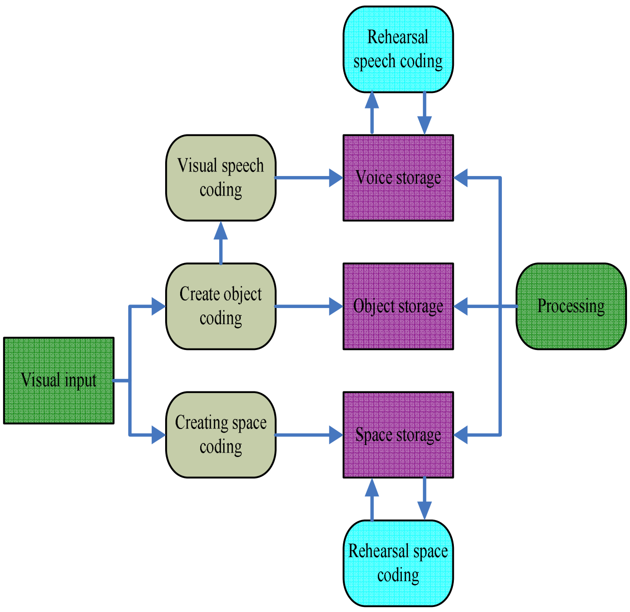

Figure 3. Composition structure and function positioning model of creative memory processing

The compositional structure and functional localization model of creative memory processing are shown in Figure 3. Many investigations suggest that a function often requires the involvement of multiple cerebral structures, and that one structural unit may participate in multiple functions. Neuropsychology, cognitive psychology, combined with brain functional imaging, separate brain functional systems (or modules) independent of each other, which, however, differ from the pluggable and removable components in computers, and may overlap wholly or partially as cranial nerve networks in morphology. The brain structures that make up these networks have a certain degree of dynamic change depending on the interaction between individuals and the environment (Lehtimaki *et al.*, 2014).

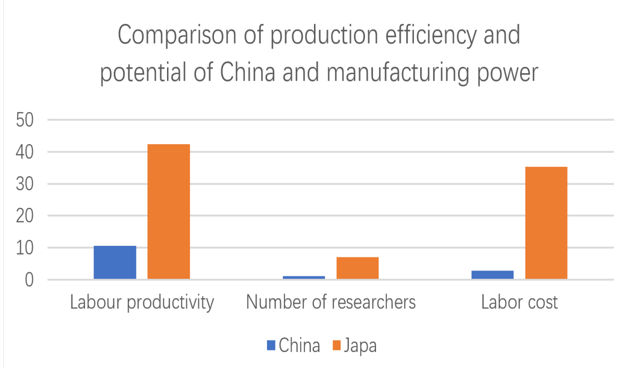

Figure 4. Comparison of production efficiency and potential of China and manufacturing power

The necessity of the cultivation of innovation consciousness in manufacturing industry

Currently, China national manufacturers depend on low-cost, low-price "cut-throat" competition to maintain their international competition advantages. In this way, it is difficult to fundamentally narrow the gap in the industrial competitiveness between China and developed countries (Rose *et al.*, 2016). A comparison of production efficiencies and potentials between China and stronger countries in manufacture industry is shown in Figure 4. In the face of the increasingly fierce competition between China and foreign manufacturers in this industry, China will vigorously develop the manufacture industry as a key technology strategy for the equipment industry, grant special funds to support the development of the manufacture industry, consolidate the constructions of engineering technology and R&D centers in a planned and systematic way, beef up the R&D investment, improve the integration and innovation capacities, strengthen the efforts to foster technological innovation capacity of the conglomerates; create a good policy and external environment for those corporations to improve their independent development and technological innovation capabilities from the perspectives of capitals, talents, and mechanisms, thus help transform China's manufacture industry from middle- and low-end product processing plant to one of the world's manufacturing center (Biggs *et al.*, 2010).

The cognitive theory model for manufacture innovation is shown in Figure 5. It includes the following processes: select related words and images respectively for auditory and visual cognition processes that occur in work innovation, which are organized into linguistic and imaging models, integrate speech and image representations with prior knowledge (Dan and Cowhey, 2012). It is required to investigate whether the investigation and application of the CN has boosted the improvement of the innovation capacity in China manufacture industry, whether it has improved the growth rate of China's endogenous economy. A model as constructed specially targets at the impact of the CN on its accumulation of human and tangible capitals. It is then concluded that the involvement of developing countries in CN will not be confined to the low-end value chain for a long time. Instead, they can accumulate human capitals to improve their innovation capacity in the manufacture industry. Empirical studies have been made with industry panel data, and it is found that during the sample period, the CN plays a significant role in the improvement of manufacturing innovation capacity, which coincides with the theoretical analysis results; the industry characteristics make a difference in the quantitative promotion effect. High technology intensive industries should improve their innovation capacities more significantly, while there is more room for improvement in the transportation equipment manufactures and other machinery manufactures; foreign direct investment, tangible capital accumulation, education level of laborers, and R&D funds can also stimulate the innovation as what we have expected (Hung and Hong, 2017).

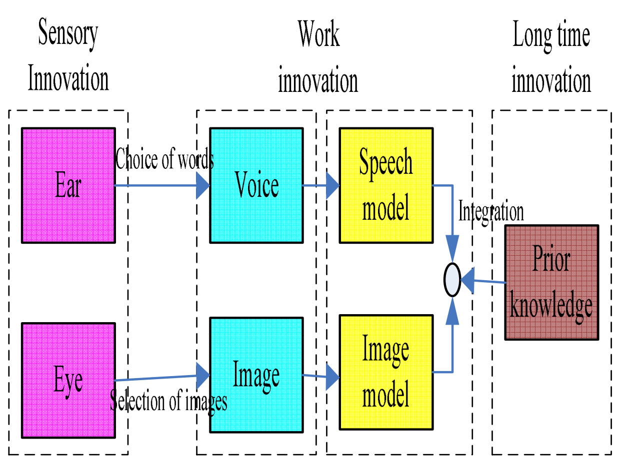

Figure 5. Cognitive theoretical model of learning

An empirical study on the role of neurocognition in the cultivation of innovation consciousness in manufacturing industry

Analysis of final product production in manufacturing industry

This model is built based on the Mbiekop. It assumes that the production factors are tangible and human capitals. On this basis, the author introduces a low-skilled labor force as another production element. Suppose there is such an economic environment where economic activity can continue infinitely (Noruzi and Westover, 2010). Each economic entity has continuous intermediates made from tangible capital, human capital, and a low-skilled labor force, which, on the one hand, can produce a composite human capital goods, and on the other hand, can obtain a tangible end-product that are tradeable, however, human capital goods cannot be traded.

The perfect competitors in any country produce tangible end-products *Yt* with CES technology. The production of *Yt* is a combination of tangible intermediates, so that the production function is:

$$Y_t = \left(\int_0^1 Y_{jt}^{\theta} d_j \right)^{1/\theta}, 0 < \theta < 1 \tag{1}$$

Where, Y_t represents the total output; Y_{jt} represents the quantity of tangible intermediatesj used; θ is positive, and represents the substitution elasticity of the intermediates. As the tangible end-product may be consumed, it may also be used as capital stock for the next period. Therefore, the following identical relation is true before the two countries trade.

$$Y_t = C_t + I_t \tag{2}$$

Where, C_t represents the total consumption; I_t represents the total tangible capital investment; assume P_{jt} represents the relative price of the intermediate j, according to the profit maximization as required, the demand function of the tangible intermediate product is:

$$Y_{jt} = P_{jt}^{-1/(1-\theta)} Y_t \tag{3}$$

Human and tangible capitals in any country can be accumulated until the next period, while the low-skilled labor force increases at a certain growth rate.

The market clearing condition for production elements in any country meets:

$$K_t = K_{xt} + K_{yt} \tag{4}$$

$$H_t = \mathrm{H}_{xt} + H_{yt} \tag{5}$$

$$L_t = \mathrm{L}_{xt} + L_{yt} \tag{6}$$

Where,

$$K_{xt} = \int_0^1 K_{it} d_i ,\ K_{yt} = \int_0^1 K_{jt} d_j ,\ H_{xt} = \int_0^1 H_{it} d_i ,$$
$$H_{yt} = \int_0^1 H_{jt} d_j ,\ L_{xt} = \int_0^1 L_{it} d_i ,\ L_{yt} = \int_0^1 L_{jt} d_j 。$$

Model construction and discussion

As above, in order to analyze the impact factors affecting innovation capacity of Chinese manufacture industry in the CN model, the author constructs an econometric model as follows:

Model 1: $$CA = C_1 + C_2 gVSS + C_3 gFDI + C_4 gPCA + C_5 gEDU + C_6 gSF \tag{7}$$

Where, CA represents the innovation capacity; *VSS* represents the influence of the CN; FDIrepresents the foreign direct investment; PCA represents the accumulation of tangible capitals; EDU represents the education level of the laborer; SF represents the R&D funds. VSS level in manufacturing industry as shown in Figure 6

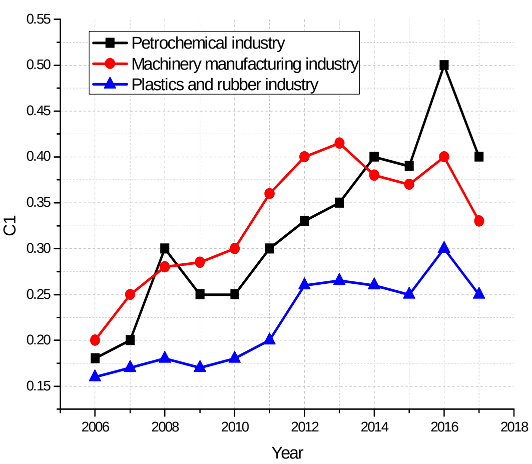

Figure 6. VSS level in manufacturing industry

In the case when a certain influence degree of the CN has played, the disparity between the CN status and technology intensity also produce an impact on innovation capacity, as shown in Fig. 6, the effect of its influence degree on the relevant manufacture industries evolves. This paper then introduces two cross terms VSS·D1 and VSS·D2, where D1 and D2 are dummy variables that represent CN status and technology intensity, respectively. If a higher level is concerned, they are assigned a value 2, otherwise, they are assigned 0, but the moderate level is assigned 1. Therefore, the model further expands to:

Model 2: $$CA = C_1 + C_2 gVSS + C_3 gFDI + C_4 gDC + C_5 gEDU + C_6 gSF + C_7 gVSS gD_1 \tag{8}$$

Model 3: $$CA = C_1 + C_2 gVSS + C_3 gFDI + C_4 gDC + C_5 gEDU + C_6 gSF + C_8 gVSS gD_2 \tag{9}$$

Given the consistency of the data, in this section, assume the number of R&D projects represents the innovation capacity. As it is more difficult to capture industry-specific data about foreign direct investment, the author uses the gross assets from foreign-invested and Hong Kong, Macao and Taiwan ventures instead. The tangible capital accumulation data is represented by the sum of the assets from the state-owned and state-holding and private ventures, and the education level of the laborers by the headcount of students in general institutions of higher education, ordinary secondary schools, and vocational middle schools. For data consistency and coherence, the investment of R&D funds is assumed as the internal expenditures for science and technology activities.

According to the studies made by Koopman *et al.*, the author has measures the domestic appreciation rate of the China manufacture industry, that is, classify the 14 manufacturers into high, medium, and low types according to their CN statuses. The higher the domestic appreciation rate, the higher the CN status, conversely the lower it is. For an industry, if DVA ≥ 0.3, the industry is a high CN industry; if 0.3 ≥ DVA ≥ 0.25, it is classified into a medium CN industry; if DVA < 0.25, it is a low CN industry. For the division of technology intensity in various industries, the author refers to the results studied by Gao Hongcheng *et al.*, and adjusts it with the manufacture segments of this paper. 14 manufacturers are classified into high, medium and low technology-intensive segments. The classification and assignment results are shown in Table 2.

Table 2. The status of neurocognitive and the assignment of virtual variables

Neurocognitive status	Industry	Domestic Value Added rate	D_1	D_2
High	Other manufacturing and waste	0.485	3	1
	Nonmetallic mineral products industry	0.418	3	1
	Paper printing and cultural and educational sports products manufacturing industry	0.398	2	1
	Other machinery manufacturing industry	0.392	2	3
Middle	Food manufacturing industry	0.386	2	1
	Wood processing and furniture manufacturing	0.377	2	2
	chemical industry	0.363	1	2
	textile industry	0.351	1	2
	Plastics and rubber industry	0.331	1	1
Low	Metal products industry	0.321	1	1
	Electrical and mechanical manufacturing	0.311	1	2
	Textile and clothing and its products industry	0.311	1	2
	Petroleum processing industry	0.201	1	1

Table 3. Model regression results

	Model 1	Model 2	Model 3
Constant term	-94.679	-98.396	-83.413
Degree of neurocognitive participation(VSS)	1.361	1.635	0.658
Foreign direct investment(FDI)	0.624	0.614	0.483
Accumulation of tangible capital(PCA)	0.474	0.47	0.555
Educational level of labourers(EDU)	9.244	9.598	9.226
Investment in scientific research(SF)	0.41	0.423	0.359
$VSS*D_1$		0.536	
$VSS*D_2$			1.478
Adjusted R_2	0.962	0.961	0.977

Eviews6.0 is used to estimate the panel data. Firstly, the Hausman test is performed on the model. It is found that the hypothesis of the individual random effect model is rejected; then the F statistics is used to test it, and found the hybrid test is passed. A hybrid model is more reasonable. The estimation results of the models 1, 2, and 3 are shown in the Table 3.

Conclusions

Today, it is the best time for China's development of the manufacture industry in history, but we should see that there are also difficulties and problems that cannot be ignored as it advances at a full speed. In the process of global competition, ventures must introduce advanced technologies in order to smoothly pile into the global market, constantly digest, imitate and innovate the technologies to reduce production costs, achieve product differential and maximize profits. It is therefore feasible that ventures not only master the design, R&D and production processes with flow and accumulation of human capitals whereby to climb up to a high-end value chain, but also encourage local ventures to involve in the application trend of global CN. Great importance should be attached to the introduction and cultivation of technical talents, while devoting major efforts to the investment in tangible capital

and R&D and improve the R&D investment structure.

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