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On the integration and development of psychology and logic within the framework of cognitive science

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心理学研究感性认识形式，逻辑学研究理性认识形式。二者密切相关但却长期分离。认知科学的建立和发展，为心理学和逻辑学的交叉融合提供了科学依据和学科框架。在认知科学的框架下，逻辑学发生了本质的变化，产生了认知逻辑新的研究框架。在这个框架下，心理学与逻辑学交叉融合，产生了心理逻辑这一新兴学科。它认为逻辑推理受心理因素影响，是由人参与的、涉身的经验科学。认知逻辑开启了当代逻辑学发展的新时代，走上了作为多学科共同工具的广阔发展道路。认知科学的发展将带来一个学科综合交叉、问题引领科学研究、科学研究引领学科建设、人才全面发展的新时代。

关键词：认知科学 心理学 逻辑学 逻辑心理学 心理逻辑

Psychology that is experiential forms of cognition (lower-order cognition), and logic that is rational forms of cognition (higher-order cognition) have long been separated although they are closely related in the original. The establishment and development of cognitive science provides a scientific basis and an academic framework for their integration. Against the background of cognitive science, logic has undergone fundamental changes, resulting in the new research framework of so-called "cognitive logic." Within this framework, the integration of psychology and logic has given birth to the new discipline of mental logic, which holds that logical reasoning is affected by psychological factors and is an embodied and participatory empirical science. Cognitive logic has ushered in a new era for the development of modern logic and enabled it to embark on the broad path of development as a common tool for multiple disciplines. The evolution of cognitive science will bring about a new era which will see the synthesis of different disciplines, problem-driven scientific research that will in turn facilitate discipline construction, and the development of comprehensive human talent.

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I. Introduction

From the 1940s on, Western philosophy began to turn to natural language as the basis for philosophical research, resulting in the birth of the philosophy of language. A large group of philosophers started to study issues related to the mind, including the relationships between the mental and the material (including the mind-body relationship), the mind and the structure of knowledge, and first person and third person perception and consciousness. From the 1950s on, Chomsky's theory of syntactic structures, Miller's theory of cognitive psychology, and the theories of artificial intelligence of Newell, Simon and Minsky offered an in-depth exploration of the human mind and human intelligence from the perspectives of linguistics, psychology and computer science. At the same time, there were also major breakthroughs in the study of the mind in science and neuroscience with the invention and use of the electron microscope and ERP and MEG technology.

Against such a background, researchers felt the need to combine these mind-related disciplines in order to study how the brain and the neuro-system process information. In the mid-1970s, the formal establishment of cognitive science in the United States was marked by three major events: Journal *Cognitive Science* founded in 1977, Sloan Foundation Report: State of the Art in Cognitive Science in 1978, and Cognitive Science Society and its first meeting in La Jolla, CA in 1979.

There are two ways in which cognitive science can be understood. The narrow one, exemplified by the Sloan Report, considers it as a computational theory of mind (CTM). The report states that: "Cognitive science is the study of the principles by which intelligent entities interact with their environments." "What the sub-disciplines of cognitive science share...is a common research objective: to discover the representational and computational capacities of the mind and their structural and functional representation in the brain."[1] The broad definition of cognitive science is exemplified in Norman's definition:

Cognitive science is a new discipline, created from a merger of interests among those pursuing the study of cognition from different points of view. The critical aspect of cognitive science is the search for understanding of cognition, be it real or abstract, human or machine. The goal is to understand the principles of intelligent, cognitive behavior. The hope is that this will lead to better understanding of the human mind, of teaching and learning, of mental abilities, and of the development of intelligent devices that can augment human capabilities in

1. E. Walker, *Cognitive science, 1978: report of the state of the Art Committee to the advisors of the Alfred P. Sloan Foundation*, p.75

important and constructive ways.[2]

We advocate the adoption of the most concise and essential understanding of cognitive science. We may want to define cognition first and then cognitive science. The mental process that generates mind activity in the brain and the neuro-system is called cognition.[3] Cognitive science is the science that studies the human mind and principles of cognition. Supported as it is by the six major disciplines of philosophy, psychology, linguistics, anthropology, computer science and neuroscience, cognitive science is the largest interdisciplinary group to date and represents a new integration of human knowledge derived from the past few millennia. The birth of cognitive science has provided a framework for the integration of multiple disciplines and heralds a new era of scientific synthesis.

This paper examines the following issues: how was it that the long separated disciplines of psychology and logic began to reintegrate and develop creatively within the synthesizing framework of cognitive science? What is the foundation for the unity of psychology and logic? Why is it that psychology has gradually become a leading discipline in the context of cognitive science? What can we expect from cognitive science? This paper tries to answer the above questions through an exploration of the academic foundations of the integration of psychology and logic as well as their relationship to each other. It also seeks to analyze some new research domains in cognitive science and indicate trends in its future development.

II. The basis provided by cognitive science for the unity of psychology and logic

Human cognition takes the following forms, ordered from the lowest to the highest: sensation, perception, image (presentation), conception, proposition and reasoning. The first three, known as experiential forms of cognition, are the research object of psychology; the last three, known as rational forms of cognition, are the research object of logic. All six are the object of epistemology, and are grouped into what is known generally as the basic and the advanced stages of cognition respectively. Therefore, psychology and logic are not only closely related in academic terms; in terms of the history of science, they were also born of and developed within the matrix of philosophy.

The following diagram of the connections among psychology, logic, philosophy and the

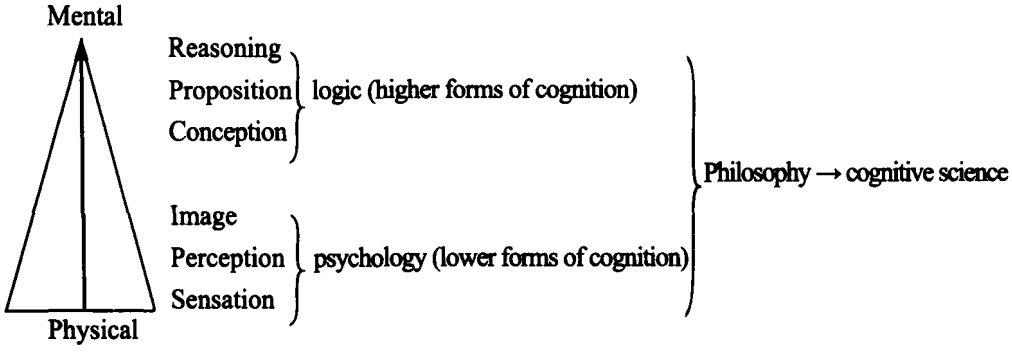
2. D. Norman, "What is cognitive science?," p.1.

3. The concept of 'mind" has been translated by many researchers as "*xin ling* [心灵]" However, I believe this is not an appropriate translation. "Soul" assumes the existence of an entity, while the mind is not an entity, but a function of the brain and neuro-system. In addition, a "philosophy of the soul" can easily be confused with the various ancient and modern philosophies of the soul, while the philosophy of mind, which is based on the development of neuroscience, came into being only after the founding of cognitive science and is totally unrelated to former philosophies of the soul.

research objects of cognitive science reveals some important relationships.

The first is the relationship among psychology, logic, philosophy and cognitive science. The triangle on the left shows that cognition begins with sensation and that experiential cognition is the basis for reasoning. The right-hand side of the diagram shows the relationship among the various forms of cognition and between them and psychology, logic and philosophy. Psychology studies the lower forms of cognition, including sensation, perception and image (presentation) while logic studies the advanced forms of cognition, including conception, proposition and reasoning. The up arrow in the center of the left-hand triangle has many levels of meaning. First of all, it shows that human cognition develops from lower to higher forms and that the lower forms of cognition await progression to the higher ones, while the higher forms of cognition contain the lower ones. Secondly, it shows that the lower forms of cognition are directly related to the human body and largely involve physiological activity, while higher forms relate to the human mind and involve mental activity to a greater extent. For instance, sensation and perception are physiological activities, lower forms of cognition that even animals engage in, but proposition and reasoning based on language are mental activities specific to human beings. Thirdly, the higher the cognitive form, the more abstract it will be, the more it will fall within the sphere of mental activity, and the lower the level of individual difference will be. On the other hand, the lower the cognitive form, the less abstract it will be, the more it will fall within the sphere of physiological activity, and the higher the level of individual difference will be. The last two features go beyond the field of philosophy into that of cognitive science. The arrow on the right means that philosophy is one of the source disciplines of cognitive science.

Diagram 1: Relationships among psychology, logic, philosophy and cognitive science.



The second relationship is the one between the mental and the physical and between consciousness and unconsciousness. For cognitive philosophy, one of the sub-disciplines of cognitive science, the most profound and enduring question is the classic issue of the relationship between the mental and the physical. This is closely related to and derives from

that perennial issue in the history of philosophy, the mind-body relationship. At the same time, the field has drawn on modern scientific findings, particularly in neuroscience. It needs to be pointed out that cognition differs from the concept of knowledge in classical philosophy. The epistemology of classical philosophy was constructed in a framework that pitted subject against object and rational cognition against experiential cognition. This framework also pitted logic and psychology against each other, as Frege indicates. It was hence only natural that psychology, which was devoted to the study of the lower forms of mental activity, was excluded from logic. After the establishment of cognitive science, this type of traditional philosophical speculative theory, with its lack of support from experimental research, was abandoned. At the opening of their book *Philosophy in the Flesh: the Embodied Mind and Its Challenge to Western Thought* (1999), Lakoff and Johnson make three statements: "The mind is inherently embodied"; "Thought is mostly unconscious"; and "Abstract concepts are largely metaphorical."[4] These three statements are considered the three great discoveries of cognitive science. Within the framework of cognitive science, mind and body are reunited, as are human mental and physical (mainly neural) activity, and even conscious and unconscious behavior within mental activity. Since the birth of cognitive science, the intersection of many research fields has brought about the integration of a number of disciplines. For instance, philosophy's shift toward cognition has resulted in the integration of philosophy and cognitive science and brought about the birth of the philosophy of mind. Similarly, the reintegration of psychology and logic has resulted in the birth of mental logic and logical psychology.

The third relationship is that among cognition, language and recognition. As mentioned earlier, cognition differs from recognition mainly in that traditional epistemology discussed the relationship between the subject and the object (world) within a framework of opposition between subject and object. Such epistemology neither needed nor was capable of verification through scientific experiments, since it was merely a type of philosophical speculation. The logical positivists tried to change this way of knowing the world and solve the problems inherent in traditional philosophy by analyzing its concepts, propositions and arguments with the help of artificial language and logic systems, dismissing any problems this approach could not solve as "metaphysical." This methodology brought about the birth of analytical philosophy and the wave of formalism that swept the Western academic world and remained in fashion in Western philosophy for several decades. After Gödel's proof of the incompleteness theorem in 1931 and Wittgenstein's establishment of language-game theory in his later years, philosophers realized the limitations of artificial language and formal systems and returned to natural language. The result was the birth of the philosophy of language, which differs from

4. George Lakoff, and Mark Johnson, *Philosophy in the flesh: the embodied mind and its challenges to Western thought*, pp. 5-6

traditional philosophy and analytical philosophy in that it changes the discourse system and narrative methods of philosophy. It contends that the subject of knowledge can only reach the objective world through the use of language, and studies language and philosophy using a threefold framework of syntax, semantics and pragmatics. Within this framework, what philosophers see is not an objective world, but one described by language; they cannot change the world directly, but must do so by constructing social realities through language.[5] This philosophy of language, symbolized by the later Wittgenstein, remained in fashion in Western philosophy for another few decades.

The philosophy of mind was born with the establishment of cognitive science in the 1970s. It no longer takes language behavior in itself as the object of philosophy, but rather sees it as a reflection of mind activities; it is these mind activities that are the object of philosophy. The philosophy of mind has drawn on positive discoveries in cognitive science, particularly neuroscience, including the following: the human cognitive process is a process in which the human brain processes information; sensation is the acquisition of information; perception and recognition explain information by assigning meaning; learning and memory are the storage and revision of information; thought and consciousness are the use of and rumination on information; decision is the prediction of future conditions and of the consequences of activities in the outside world; motor control serves as a guide to activities; language is a tool for communication, including interpersonal communication, interaction between people and machines, and information exchanges between people and their environment. The philosophy of mind developed from and is rooted in traditional philosophy, analytical philosophy and philosophy of language. The three classic philosophical issues related to the mind are (1) The Mental-Physical Relation (including the mind-body problem and Descartes's *dualism*); (2) The Structure of the Mind and Knowledge (including rationalism and empiricism and the relationship between the two); and (3) The First- and Third-Person Perspectives (including self-knowledge and the problem of other minds). These classic issues in traditional philosophy and the philosophy of language contain the seeds of the philosophy of mind, but they are ultimately not the same thing. Although issues in the philosophy of mind have grown out of traditional philosophy and the philosophy of language, it differs from all earlier philosophical theories in that it has its own particular research object. It observes and studies not only the cognitive phenomena related to mind and language (higher-order cognition), but also those related to the body and the unconscious (lower-order cognition). In this way, philosophy of the mind not only can reintegrate but has reintegrated logic and psychology.

5. Cf. John R. Searle, *Social ontology, logic, methodology and philosophy of science: proceedings of the Thirteenth International Congress.*

III. Certain developments in mental logic

Mental logic is a new theory of logic that takes mental factors as independent variables and logic factors as dependent variables, say, function. It treats human mental activity as logical thinking, or, it maps human mental activity on to logical reasoning. Therefore it contends that logical thinking or reasoning is affected by psychological factors.

Wason's selection task can serve as a full demonstration of this feature of mental logic. The experiment was designed as follows. Subjects are presented with four cards, each of which has an English capital letter printed on one side and an Arabic numeral on the other. The subjects are asked to turn over the fewest possible cards among the four cards presented to test (prove or disprove) the following rule:

R1: If the letter shown on one side is a consonant, the other side will be an odd number.

This allows for the cards to be organized into a large number of groups, such as S3A2, EK69, AB47, etc., to test what constitutes sufficient conditions for hypothetical reasoning. For instance, in the group S3A2, flipping S shows that the subject knows how to use Modus Ponens (MP), while flipping 2 shows the subject knows how to use Modus Tollens (MT). Both forms of reasoning are correct. Flipping 3 shows that the subject used MP and flipping A shows that the subject used MT; both are incorrect. The statistical findings of experiments by Marcus and Rips[6] showed that almost 100% of subjects knew how to use MP in their reasoning, but only about 50% could use MT, showing that most people find the latter much more difficult. Although MP and MT are equally correct forms of reasoning and are given the same weight in logic, most subjects do not see it that way. Why is this? On the other hand, more than half of the subjects used MP or MT incorrectly, with the former accounting for 33% while the latter accounted for 21%. Again, why is this?

The reason is in that in R1, "consonant" and "odd number" are indicated, but "non-consonant" and "non-odd number" are not. Therefore, in the valid reasoning model, more subjects chose to flip a card that showed a consonant rather than one with an even number, and in the invalid reasoning model, more chose to flip a card with an odd number rather than one with an even number. This proves that the human reasoning process is affected by psychological factors. In other words, logic is not abstract, but concrete; psychology is not irrelevant to logic, but rather the opposite.

What is interesting is that the results of reasoning are affected by small changes in the relevant rule or task; see below.

R2: To drink alcohol in public, one must be of legal age (18 years old).

The subjects were asked to imagine themselves to be a police officer walking into a bar

6. S. L. Marcus, and L. J. Rips, "Conditional reasoning."

to check whether any illegal underage drinking was going on. The task design involved completing the job by flipping over one or more cards out of four. The four cards showed the following: (1) drinking alcohol; (2) drinking cola; (3) 16 years old; (4) 22 years old.

This selection task was the same as the previous one as far as the form of logical reasoning was concerned, but it was more concrete (the concrete Wason selection task) than the first (the abstract Wason selection task). The results showed that the score of subjects using MP was unchanged from the first experiment, but the score for those using MT showed a substantial increase. Even among those who had not been able to complete MT in the abstract experiment, as much as 72% of subjects gave correct answers![7] This experiment shows that both environment and experience affect the results of people's reasoning.

Since 1966, experiments using the Wason selection tasks have been repeated in various forms with the same results: reasoning is affected by psychological factors, the reasoning environment and special experiences. A new field of logic, mental logic, has gradually grown out of research on the way psychological factors affect logical reasoning. Within the framework of cognitive logic we have delineated here, mental logic is a sub-discipline within cognitive logic. Both play an important role in cognitive science research.

IV. Discussion and brief conclusions

Finally, this paper discusses and tries to answer a few important questions.

1. Why is it that psychology has gradually become a leading discipline in the context of cognitive science?

The history of psychology shows that for a long time psychology was attached to philosophy, and it is only in relatively recent times that it has sought once again to attach itself to science. However, during the short span of thirty years since the establishment of cognitive science, psychology has gradually developed from a marginal subject struggling for its survival into a "leading discipline" closely related to cognitive science. The reason for its change of status can be found in the common nature of cognitive science and psychology.

In essence, cognitive science runs counter to the principles of science and philosophy of the twentieth century or even earlier. Prior to the establishment of cognitive science, scientific theories, including logic, mathematics and physics, all set themselves the task of seeking universal principles, while philosophy sought to find an even more universal "first principle."

However, despite their universality, science and philosophy were unable to answer the following question: if the principles of science and philosophy (logic) are universally

7. R. A. Griggs, and J. R. Cox, "The elusive thematic-materials effect in Wason's selection task," pp. 407-420.

applicable, and we all think in accordance with these principles (for instance, we all think and compute in accordance with the same logical models and mathematical formulas), why do we draw different conclusions when faced with the same phenomenon or reach different solutions for the same problem?

It is precisely individual differences that cognitive science seeks to deal with. What is called cognition refers to the process whereby the brain and the neuro-system generate mind activities. Therefore, not only do human beings possess minds, but animals also possess some kind of mind. The human mind, however, is quite different from that of animals in that animal cognition is a simple signaling system, stimulus-response model based on instinct while the human mind is a complex form of cognition guided by intention and based on processing by language systems whose mechanisms include the interaction of such elements as language, psychology, physiology, emotion, society, logic and philosophy. Since human beings are also animals, their cognition model also contains evolutionary mechanisms similar to those of animals. Since the establishment of cognitive science, various new sub-disciplines have emerged for the study of its various ramifications, such as philosophy of mind, cognitive psychology, language and cognition, cognitive anthropology, cognitive computer science or artificial intelligence, and cognitive neuroscience; each conducts research on the cognitive model most relevant to its domain.

Since mind is a function of the brain, it must be embodied, because the brain is part of the body. As different animals have taken different evolutionary paths, their brains and neuro-systems vary greatly; there are characteristic differences between the minds of different animal species and between the animal and the human mind. As with different animal species, different nationalities (despite belonging to the same species) show major differences in cognitive model. For instance, Asian cognitive models differ from Western ones, and South Chinese cognitive models are different from Northern Chinese ones even though both are Chinese. Even identical twins, who have the greatest genetic similarity possible, show different cognitive characteristics. Recent studies have shown that Westerners are more likely to accept deductive reasoning premised on counterfactual reasoning (96%) while the Chinese find this type of reasoning difficult to accept (6%).

The disciplinary characteristics and goals of psychology are similar to those of cognitive science. In terms of disciplinary characteristics, psychology is similar to cognitive science in two respects: it is embodied, and it is experiential. The fact that it is embodied can be seen from two perspectives. First of all, the research object of psychology is also mind, which, as indicated earlier, is embodied. Secondly, from the perspective of the relationship among psychology, logic, philosophy and cognitive science shown in Diagram 1, psychology studies a lower order of knowledge than logic, so it naturally has a closer relationship with the body. In terms of disciplinary goals, psychology also needs to solve the problem of individual

differences in knowledge and cognition. Previously, researchers thought that as psychology took as its research object people's varied and constantly changing psychological activities, it could not possibly have any kind of laws nor could it be objective, and therefore it could not possibly become a science, any more than art could. Since the establishment of cognitive science, the idea that the science is simply a matter of seeking universal rules has changed completely; researchers have recognized that science seeks not only the universal principles of human cognition, but also its individual differences. Since psychology is characterized by the exploration of individual differences, it was accepted by cognitive science from the very beginning. Psychology has become a part of cognitive science and also, of course, a part of science.

The historical and logical similarities between psychology and cognitive science mean that the two have depended on and supported one another and developed together over the past fifty years. In the course of this process psychology has grown into a leading discipline and cognitive psychology has become the mainstream of modern psychology.

2. How can logic and other general sciences benefit from cognitive science?

The birth of cognitive science has presented a challenge not only to the various academic disciplines that seek universal truth, such as logic and philosophy, but also to the whole of Western thought, which is based on induction and rationality. Here I would like to take logic as an example to explain how academic disciplines that seek universal truths should respond to such a challenge.

Syllogisms, hypothetical reasoning, and propositional and verbal logic were once considered universal principles which seemed applicable not only to the ancient Greeks but also to modern Europeans and Americans, and even to modern Chinese. Faced with these "eternal and universal truths" that held regardless of time and space, it seems that nobody wondered how pre-modern people in China and India, both birthplaces of logic, managed to think correctly and communicate effectively, despite the fact that neither had been in contact with ancient Greek logic or early modern Western logic. Why, then, should the Western logic derived from ancient Greece be considered universally applicable and given "priority" among the three major systems of logic? As I see it, an important reason is the rise in the early modern period of a science based on deductive and inductive logic. Theoretical science marked by respect for universal principles was wholly consistent with classical Western logic, with its deductive and inductive reasoning, and experimental science based on empirical facts used the methodology of deductive reasoning. That is why Chinese logic, which is characterized by experience and analogy, has not been given its due position in modern science.

Since the founding of cognitive science, the traditional views of logic and methodology described above have been questioned. Lakoff contends that cognitive science has destroyed

long-held hypotheses about human reasoning and predictive ability. Its discoveries have provided a completely new and detailed understanding of the fundamental question "What is man?" According to Lakoff and Johnson, there is no Cartesian dualistic person, no Kantian radically autonomous person, no utilitarian person, no phenomenological person, no poststructuralist person, no Fregean person, no computational person, and no Chomskyan person.[8] The discoveries of cognitive science are better explained by Chinese logic than by Western logic. For instance, metaphor uses analogy as its logical method, and both ancient and modern Chinese logic are rich in metaphor. The birth of cognitive science has brought about a new era for Chinese logic.

Against the background of cognitive science, the discipline of logic has undergone fundamental changes. If we put the hexagonal framework of cognitive science against the background of modern logic, we see new research fields and disciplinary groupings derived from the intersection of modern logic and cognitive science, including cognitive logic including philosophical logic; mental logic; the logic of language; cultural and evolutionary logic; the logic of artificial intelligence; and the logic of neuro-systems. I call this new research framework "cognitive logic."[9] The establishment of cognitive logic has opened a new era for the development of modern logic, enabling it to forsake the narrow path of confinement to basic mathematical research and reasoning and embark on the broad path of development as the common tool of multiple disciplines.

In what ways can logic benefit from cognitive science within the framework of cognitive logic?

Philosophical logic. Philosophical logic includes basic logic, that is, extensions of and alternatives to classical logic, as well as the systems of logic that based on basic logic and related to traditional philosophical issues. The development of philosophical logic has taught us that we should give up the position of treating logic as a "legislator of thought." The reasoning models of logic (syntactic or semantic models) are merely models of thinking defined by logicians rather than the reasoning models actually used. Logic is a tool, and tools are man-made and multifarious. Every theory of logic is a relative truth system within the field in which it applies and logic has no "absolute truth reference system." Any attempt to use a particular theory of logic as an absolute benchmark or to use one theory to supplant another will prove wrong in theory and harmful in practice.

The logic of language. The logic of language is the result of logic's return to natural

8. Cf. George Lakoff, and Mark Johnson, *Philosophy in the flesh: the embodied mind and is challenges to Western thought*, pp. 5-6.

9. Cai Shushan "Logics in a new framework of cognitive science: on cognitive logic, its objects, methods and systems."

language. It draws on the research methods of such formal types of logic as mathematical logic, modal logic, and multiple-value logic etc. What the logic of language teaches us is that we should pay close attention to the link between logic and language, particularly natural language, and to the use of logic in daily language and daily life. Logic models are not abstract forms or dogmas, but living mechanisms used by people to meet their needs. Therefore, logic needs to be concerned with people. It should not concern itself only with the systemic structure of language symbols (e.g. syntax), but also with the representation and meaning of language symbols (semantics), and even more with the effect of language users and its environment on the meaning of what is said (pragmatics).

Mental logic. Mental logic grew out of the intersection between logic and psychology. What mental logic shows us is that people's mental states affect their logical thinking (mental logic), while at the same time logical thinking affects mental processes and states (logical psychology). Mental logic serves as a bridge between psychology and logic, and thus breaks through the artificial barriers that have existed between the two since Frege. Since psychology and cognitive science are embodied, as is cognitive logic, logic must also be embodied. Mental logic has enabled us to better understand Lakoff's famous observation that "The mind is inherently embodied; thought is mostly unconscious; abstract concepts are largely metaphorical."

Cultural and evolutionary logic. This type of logic is a new discipline that has grown out of the integration of logic and cultural anthropology and devotes itself to the study of the logical characteristics of human culture and human evolution as well as the influence of different cultural backgrounds on logical thinking. Cultural and evolutionary logic has provided us with the following way of thinking: logic is not something that belongs to all mankind: it differs with different peoples and cultures. For instance, Eastern and Western logic are quite different. Western logic reveres rationality and deductive reasoning, while Eastern logic stresses experience, inductive reasoning and analogy. However, different systems of logic that reflect different cultural backgrounds and ethnic characteristics are not mutually exclusive. Rather, they complement and are compatible with each other, since all obey the common principles of human cognition. The development of cognitive science, with its attention to experience and individual differences, provides Chinese logic with an opportunity: we should strengthen our research on ancient, early modern and modern Chinese logic.

Logics in artificial intelligence. This is the logic theory of machine intelligence, a field with a history as long as that of cognitive science. Logic in artificial intelligence is one of the most active fields of modern logic. What it tells us is that people cannot reach freedom in the world they have created, as Gödel has pointed out. Although Gödel states that consistency and completeness cannot both be achieved in a sufficient large formal system, we can still do something since we possess a finite or infinite number of consistent and complete sub-systems.

This is the partially formalized strategy of artificial intelligence. Pessimistic views seem always to have the upper hand in this field. Penrose has asserted that machine intelligence can never surpass human intelligence. Searle's conclusion is even more depressing, since he believes that today's digital machines can only imitate human intelligence but can never possess *any* intelligence of their own. Fortunately he still considers that future non-digital computers may possibly possess true human intelligence, a position that leaves some room for the development of logic in artificial intelligence. Logic theories for quantum computing and bio-computing have become frontier fields that promise breakthroughs in the logic of artificial intelligence. Despite the many taboos in this field, with its long history, progress is being made.

Logic in neuro-systems. Logic in neuro-systems is the result of the integration of logic and neuroscience, just as logics in artificial intelligence are the result of the integration of logic and computer science. The difficulties encountered by human beings in the field of artificial intelligence have turned them to learning from the human brain and the human neuro-system. What this new discipline has made us realize is that the human brain, which has evolved into what it is today over the four billion year evolution of life, remains the most complex and most advanced cognition system. Since the invention of writing, the human soul has been searching everywhere, but now it is returning to its dwelling place. The neural network computer, which is one of the twenty-first century's most promising inventions in terms of a breakthrough in the field of intelligence, has as its theoretical foundation the logic of neuro-systems. Human mind started by exploring the outside world and then finally returned to explore humanity itself, which shows that human beings need to achieve a better and more comprehensive understanding of themselves. We need to wait and see what will come out of the combination of the most complex and advanced symbolic system (software) invented by human beings and the human brain (hardware), the most complex and advanced cognition system that the long process of evolution has produced.

3. Our expectations for cognitive science

As the largest new interdisciplinary science of the twenty-first century, cognitive science has two missions: to unravel the mysteries of the human mind, which is its mission as a science; and to promote the development of the relevant disciplines, which is its mission as a discipline. Both are related to the integration of psychology and logic we have discussed above.

The Human Cognome Project (HCP) and Human Genome Project (HGP) are seen as the two great scientific projects that are expected to change people's way of life and improve their survival capacity. Scientific research has found that the differences between species revealed by genetics are very slight, and the differences between ethnic groups within the human species are even slighter. To take it down to the individual level, identical twins, for example,

carry exactly the same gene expressions, but there are still major individual differences between them. Therefore it can be seen that genetic inheritance is not the only factor, and not even the major factor, in determining the differences between species and between individuals, and that individual differences in cognition and behavior need to be explained by theories of cognitive science.

The twentieth century was the age of analysis, with researchers putting their energies into categorizing different fields of study. But the twenty-first century will be the age of synthesis, with researchers carrying out the integration of research and knowledge from related sciences. The birth of cognitive science has made it possible for us to carry out interdisciplinary synthesizing research in intersecting fields.

Cognitive science is not only the scientific basis for the unity of psychology and logic, but also the hope for their coordinated development. However, we hope for more than this from cognitive science. First of all, we hope cognitive science will be able to break down the opposition and division between many disciplines. Despite the fact that there are innumerable reasons for them to be unified, unity and synthesis could only be a dream in the age of analysis before the advent of cognitive science. Secondly, we hope cognitive science will bring about a renewed age of problem-driven scientific research, which will in turn facilitate discipline construction. We are now doing what may be just the opposite: disciplinary strangles scientific research, which, in turn, loses its correct bearings. Finally, we hope the era of cognitive science will not only generate vital scientific theories, but also produce encyclopedic scholars like Aristotle in ancient times and Leonardo da Vinci in the early modern period. Since then, many experts in different fields have emerged from the meticulous analysis of isolated parts of separate disciplines, but we have lost those encyclopedic scholars and the greater cultural values they represent for human beings. The growth of cognitive science has encouraged us to expect the coming of a new era for the creative synthesis of knowledge and the all-around development of talent.

Notes on contributor

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References

Cai, Shushan. "Logics in a new framework of cognitive science: on cognitive logic, its objects, methods and systems." in *Logic, methodology and philosophy of science: proceedings of the Thirteenth International Congress, 2007*. London: King's College Publications, 2009.

Griggs, R. A., and J. R. Cox. "The elusive thematic-materials effect in Wason's selection task." *British Journal of Psychology*, vol. 73, 1982.

Lakoff, George, and Mark Johnson. *Philosophy in the flesh: the embodied mind and its challenges to Western thought*. New York: Basic Books, 1999.

Marcus, S. L., and L. J. Rips. "Conditional reasoning." *Journal of Verbal Learning and Verbal Behavior*, vol. 18, 1979.

Norman, D. "What is cognitive science?" In *Perspectives on cognitive science*. ed. D. Norman. Norwood, NJ: Ablex, 1981.

Searle, John R. *Social ontology, logic, methodology and philosophy of science: proceedings of the Thirteenth International Congress*. London: King's College Publications.

Walker, E. *Cognitive science, 1978: report of the state of the Art Committee to the advisors of the Alfred P. Sloan Foundation*. Unpublished, 1978.

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