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On Piaget's epistemological methodology and its contemporary significance

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Abstract

Piaget's works covered philosophy, psychology, biology, and logic, as well as other fields. The psychological community attaches great importance to Piaget's influence in the field. For example, he was the President of the Swiss Psychological Society, the President of the French National Psychological Federation, the President of the 14th International Union for Psychological Science, and he was awarded the Outstanding Scientific Contribution Award by the American Psychological Association (APA) in 1969.

Should Piaget's academic identity be that of a philosopher or a psychologist? This question is essentially about Piaget's methodology, as it is not the object of the study that defines which branch an approach belongs to, but the method of study it adopts. Piaget's theories are rich and complex, and his works are numerous. What connects such theories into a whole system is the constructional method of Piaget's epistemology.

This article focuses on Piaget's works in the fields of philosophical epistemology, biological analogy methodology, as well as the methodology of structuralism and dialectics, so as to analyze the key concepts in the construction process of Piaget's Genetic Epistemology. It was hoped that through such reviews, we could learn from the core constructs of Piaget's theoretical system, which are often misunderstood and ignored. It is also hoped that, by analyzing these contents, Piaget's theory can be explained as being neither psychological in the traditional sense nor philosophical epistemology in the general sense. Instead, we should think of Piaget's Genetic Epistemology as an innovative science of the mind. From this perspective, we can better understand how Genetic Epistemology can deal with many "difficult problems" faced by contemporary cognitive science.

Piaget defined his core concepts by the theory of equilibrium-construction. He demonstrated the bidirectional interaction between organisms and the external environment based on the concepts of adaptation and equilibrium in biology. Furthermore, he constructed a structuralist epistemology of Genetic Epistemology through the "isomorphism" of cognitive and biological processes.

Structuralism was not only a theoretical proposition, but a construction method of Piaget's meta-theory. Piaget established structuralism as a methodology by defining three characteristics of structure: integrality, transformation, and self-adjustment.

Piaget's way of thinking was dialectic. This dialectic referred to any two separate and different systems, not necessarily opposed to each other, which could merge and produce a new system.

Finally, Piaget's research method was a clinical interview, as well as the Geneva Discovery Technique. In terms of research methods, Piaget could be regarded as an early pioneer of qualitative research techniques.

In general, Piaget's theoretical construction method had two important characteristics. First, he emphasized that relative to the structure, function would be the precondition, in the sense of logic; that is, the function was the adaptation of the organism to the environment. Second, the ideological basis of Piaget's methodology is dialectics. His epistemology, on the one hand, criticizes rationalism, while on the other hand, criticizes empiricism, finally forming a unique epistemological system. Piaget's Genetic Epistemology may provide guidance and inspiration on many "difficult problems" in the study of the philosophy of mind nowadays, such as the "other-mind problem" and the "induction problem."

Key words Piaget, genetic epistemology, phenocopy, reflective abstraction, balance, construction

Jean Piaget's work covers philosophy, psychology, biology, and more. The psychological community attaches great importance to Piaget's influence in this field. For example, he had been elected as the president of the Swiss Psychological Society, the president of the Association Francophone countries, and the 14th president of the International Union of Psychological Sciences. In 1969, he was awarded the Distinguished Scientific Contribution Award by the American Psychological Association. Philosophical circles also place great importance on Jean Piaget's academic identity. He had said in his book, *Insights and Illusions of Philosophy* (1965), "During my career as a psychologist and epistemologist, I have been on excellent terms with philosophers, who have often honored me with their friendship and confidence, which I have greatly appreciated. " (Piaget, 1965/71, P XIV). "Honored me with their friendship and confidence" refers to the fact that Jean

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Piaget had even been elected a member of the International Institute of Philosophy, without putting himself forward as a candidate. It is also in this book that Jean Piaget is unapologetically critical of the top-down "inspiring" approach of philosophy as it fails to provide us with real knowledge, and thus firmly chooses the scientific path.

Piaget himself, in contrast, encountered criticism that his research methods were not scientific enough (Lu, 1982). In a sense, it is precisely this criticism that made Piaget's theory suffer from a certain bias. So much so that today's researchers often lament that Jean Piaget is out of date (Li, 2010). Thus, the study of Jean Piaget presents a paradox: on the one hand, most researchers do not deny the significant contribution and influence of Jean Piaget's theory; but on the other hand, Jean Piaget's theory has not received enough attention at the present time, and research on Jean Piaget has become increasingly rare. If a theory is so powerful and so important, why is it so rarely studied?

The richness and complexity of Jean Piaget's thinking, his numerous writings, and the wide range of disciplines involved make it difficult for us to understand and grasp Jean Piaget's theory as a whole today. This paper intends to trace the methodology of Jean Piaget's Genetic Epistemology (GE) and comb the logical relevance of his related works. For a theoretical system, research methods are often the basis for defining its subject category. The criticism of Piaget's research method implies that scientific psychology does not agree with Jean Piaget's academic identity: Should Piaget be academically identified as a philosopher or a psychologist? Should Jean Piaget be a philosopher or a scientist? The ambiguity of the academic identity makes later researchers not willing to accept Jean Piaget as a peer. This may be one reason why Jean Piaget's research has hit a snag today.

In this paper, we will review previous research on Jean Piaget's work in the fields of epistemology, the methodology of biological analogy and methodology of structuralism. This paper reveals the logical connection between several core categories in Piaget's theory system, and presents the significance of dialectics as Piaget's thinking method on the basis of the existing research. In fact, dialectics constitutes the starting point for the constructivism of Jean Piaget's Genetic Epistemology. It is hoped that through the analysis of these contents, we can form a completely new understanding of Jean Piaget's academic identity: Piaget's theory is not psychology in the traditional sense, nor is it philosophical epistemology in the general sense. Rather, we should think Jean Piaget as a genetic epistemologist in the field of innovative science of the mind. In this perspective, we can give up some misunderstanding and prejudice about Piaget's theory and realize the significance of Genetic Epistemology to many "difficult problems" of cognitive science.

1 Core concept definition: From phenocopy to reflecting abstraction

A core set of concepts in GE is derived from biological studies through the construction of equilibrium. The shift from biology to epistemology revealed Jean Piaget's theoretical creativity.

Piaget's theory of biology presupposes the evolution that organisms evolve by "adapting" to their natural environment. But the evolutionary theory (ET), which Piaget had chosen, was a type of interactive ET between subject and object. He had criticized both exogenous Lamarckism and endogenous Neo-Darwinism. Lamarckism emphasizes that environmental stress causes organisms to adapt, solidifying the change into genetic factors that make the adaptation of individuals an adaptive evolution of species. The impetus for change comes from the external environment, and the internal genetic mechanism only passively accepts the impact of the environment. The process is exogenous. Neo-Darwinism is a combination of classic Darwinism and modern genetic theory. The theory holds that organisms evolve on the basis of random mutations in their genes, the result of which is passive acceptance of environmental selection. In this process, there is no necessary connection between the organism's internal mechanism, its genes, and the selection of its external environment. Individual survival and reproduction is only a probability event between genetic variation and environmental selection. Thus, Neo-Darwinism is endogenous (Piaget, 19671971989; Messerly, 2009).

The main problem with Lamarckism is that "the heritability of acquired experience" has never been supported by biological evidence. Piaget noted this, but it was not his main reason for criticizing the Lamarckism. In fact, Piaget had also been gathering biological evidence to support "the heritability of acquired experience"[1]. In Piaget's view, the Lamarckism and the Neo-Darwinism had both ignored the initiative of the internal mechanisms of the organism and the interactions between the inside and the outside. Lamarckism sees organisms as passively accepting the actions of their environment; Neo-Darwinism sees individual variation as purely haphazard, and organisms as simply passively accepting these variations and environmental selection for them. Piaget argued that the common mistake of both theories was that, whether the source of evolutionary motivation was exogenous or endogenous, they first assumed that there was no interaction between external and internal mechanisms. Piaget was influenced by Henri Bergson's Creative Evolution that organisms respond to environmental demands proactively, creatively, and purposefully (Bergson, 19412004). Biological evolution is an interactive constructive process between endogenous and exogenous factors. That is, only when the internal mechanism of an organism interacts with its external environment can a new structure of an organism be constructed (Piaget, 1974/1980). Thus, Piaget's theory of evolution is constructive.

Piaget thus introduced the concept of "phenocopy" to explain the interaction between the external environment and internal mechanisms.

"Phenocopy" refers to the reverse effect of phenotype on genotype, which is the "imitation" and "replication" of the genotype to the phenotype, and "the so-called replication is actually the reconstruction (of genotype) based on organic selection" (Piaget, 1974/1980). The impact of phenotypes to genotypes can be explained in a number of ways, the simplest of which is by the "law of use and disuse" of Lamarckism, and the modern evolutionary synthesis of "natural selection" as a possible explanation. However, Piaget chose the third option that "the genotype replicates the previous phenotype." This explanation was first proposed by Rennaz Lerner in 1956 (Piaget, 1976/1978). Lerner continued the view of Bergson's

[1] Refer to Jean Piaget's discussion in *Structuralism* (2007, pp. 37−43).

"Creative Evolution", emphasized that evolution is purposeful and that organisms have an active choice in their evolution (Bergson, 1949/2004). Phenocopy is the biological basis for the active evolution of organisms.

Jean Piaget had studied the phenocopy of Limnaea stagnalis and a Sedum parvulum. When Limnaea stagnalis was living in calm lakes, the shells were longer, and in fast-flowing streams, the shells were shorter to accommodate the impact of the current. Piaget cultured snails in an artificial environment in an aquarium to examine the relationship between changes in water flow conditions and changes in snail shell morphology. After about five or six generations, he found that the phenotypic changes showed a pattern of genotype consolidation. When sedum grows at different altitudes, plant height and leaf size also change. Piaget also observed examples of phenocopy in these plants (Piaget, 1976/1978).

According to the viewpoint of active evolution, the interaction between the internal mechanism of an organism and the external environment constructs the phenotype. There is a two-way interaction between phenotype and environment, in which genotype determines phenotype and phenotype reacts to genotype by phenocopy. Thus, through the mediation of phenocopy, a reciprocal interaction is established between the internal mechanisms of an organism and its external environment (Figure 1). In this process, the impact of internal mechanisms in the external environment is called assimilation, and the active regulation of internal mechanisms is called accommodation. The result of assimilation and accommodation is to construct an equilibration between inside and outside of an organism, which is adaptation.

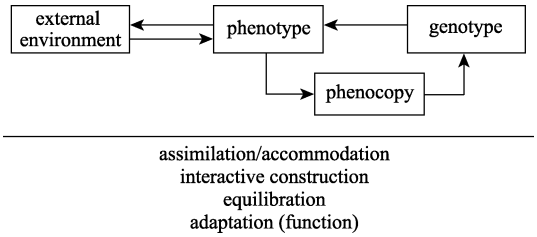

Figure 1. The interactive construction process between organism and external environment.

According to this model, when the environment changes, the balance between the phenotype and the environment is disturbed. Under environmental pressure, the phenotype needs to be adjusted to adapt the environmental effect. For example, in turbulent water flow, the snail needs to be attached to the rock harder, and the pull of the muscles on the shell increases, making the shell grow wider and shorter over time. When phenotypes change, there is a corresponding imbalance in the internal mechanism of the organism; that is, there is an adaptive disequilibrium pressure between phenotypes and genotypes. Under such pressure, genotypes make an accommodative adjust, namely phenocopy (Piaget, 1977a/1995; Piaget, 1979/1995). In this process, the regulation of genotype is not random and passive, but active and purposeful. Finally, a new balance is established between the internal mechanism of the organism and the external environment through two-way interaction. This kind of equilibration is a new balance between new environments, new phenotypes, and new genotypes. Thus, "biological evolution is a constructive process" (Piaget; 1974/1980; Piaget, 1977a/1995).

Despite the lack of sufficient biological evidence for phenocopy, Piaget accepted it on the theoretical level and believed that biology would provide sufficient evidence to support the concept.

From a viewpoint such as this, a degree of generality in the process of the phenocopy becomes reasonable and even quite probable. On the one hand, this would simply mean that conquest of environment, besides being considered an extension of the basic assimilatory tendency of life, usually begins with simple trials by phenotypic accommodation or by empirical knowledge. On the other hand it means also that, by virtue of internal requirements of equilibration, these trials will subsequently give rise to more secure forms of assimilation. These in turn would be ranged in ascending degrees over every level of development, beginning with that of "genetic assimilation" (to retain Waddington's term for the consolidation of mutations by organic selection) or the copy of well-accommodated phenotypes (in other words the reconstruction, if our interpretation of the phenocopy is accepted), and ultimately attaining the various levels of cognitive assimilation, including those of scientific thougnt. (Piaget, 1974/1980)

With this step in his argument, Piaget transferred this constructive biological model to the cognitive process (Piaget, 1977b1995). Cognitive processes are, in Piaget's words, "isomorphic" to biological processes. According to Piaget, knowledge acquisition is neither exogenous nor endogenous, but the result of the construction of the interaction between the cognitive subject and the object. In cognitive models, "the cognitive equivalent of phenocopy" is "reflecting abstraction" (Piaget, 1974/1980).

"All new knowledge is premised on abstraction" (Piaget, 19741980), Piaget had argued, but abstraction can be divided into two types. Abstractions of extrinsic experiences are "direct" and "simple" ways in which children perceive the world, such as placing a weight in their hands, thus achieving an abstraction of weighty. The second kind of abstraction is "the case that encompasses all logical-mathematical abstractions". We can call it 'reflective abstraction' because it is not a direct abstraction from the object itself, but an abstraction of coordination or operations themselves (Piaget, 1974/1980). The reflexive abstraction constitutes the inverse function from experience to the internal operation. This effect is equivalent to "phenocopy" from phenotype to genotype, resulting in the isomorphic between the model of cognitive-construction and the biological model (Figure 2).

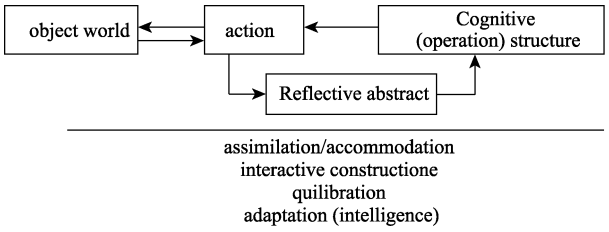

Figure 2. The interactive construction process between cognitive structure and object world

The continuous line between the cognitive models and the biological models, are the concepts of "assimilation" and

"accommodation", "construction" and "equilibration". These concepts also formed the conceptual basis of Piaget's GE (von Glassfeld, 1979, 1982).

In Piaget's theory, equilibration was both a state and a process, while Piaget emphasizes its procedural meaning. When an organism adapts to its environment, a temporary equilibrium is achieved; when the environment changes and the organism is no longer able to adapt to the environmental conditions, it is "de-equilibrated". De-equilibration will cause the organism to make necessary adjustments to restore equilibrium. It can be seen that the process of "equilibrium -- de-equilibrium -- re-equilibrium" ultimately points to the adaptation of individuals to their environment.

The cognitive model, which is identical to the biological model, is constructed through the process of "equilibration--de-equilibration--re-equilibration". In the cognitive model, "action" is an interactive interface between internal mechanism (cognitive structure) and external mechanism (object world). "Action", in Piaget's sense, includes the actual physical action (act) at the sensor-motor level, the operation of the pre-operation level against the representation, and the operation of the concrete operational level against the symbol, and the operation of proposition and relation at the level of formal operation.

Firstly, under the dual effects of the inside and outside, children establish a scheme for a specific environment through the coordination of perception and movement. For example, children have found that "a bell makes a noise when pulled on a rope", which is a scheme of action. It means that the child has established an equilibration between the cognitive structure and the environmental object. It's a kind of adaptation. When the environmental factors changed, for example, when a child encounters a new bell, instead of pulling the string up and down, the child needs to establish a new pattern of movement. For the external object world, the action is an individual's abstract response to the external world, while for the internal cognitive structure, action forms a new form of the higher-order exponential scheme on the basis of various primary action forms through "reflective abstraction", for example, through the reflective abstraction of the action forms of pulling the rope, children form the active (operational) scheme on higher levels such as "causality", "force" and "transmission". The formation of the new active scheme is that children realize the reconstruction of the operation structure on the cognitive level. This is the equilibration of the child's abstraction on a higher level. The new active scheme has a wider range of adaptability, so that children's cognitive abilities develop to a new level.

In the process of equilibration--de-equilibration--re-equilibration, the interaction between the environment and the internal mechanisms of the organism involves both assimilation and accommodation. That is why this process is "constructive", and not just the passive acceptance of exogenous interventions or the random variation of endogenous factors (Piaget, 1950). Therefore, we can say that cognition is just the process of the interaction of individual exogenous and endogenous factors on the "action as interface" and the formation of a new "adaptability".

2 Construction of meta-theory: Function in advance logically of structure

The theoretical goal of Piaget's GE was to address the origin of knowledge in a scientific context (Piaget, 1972/1981). Since Ancient Greece, epistemology has been confined to two main traditions, rationalism and empiricism. The tradition of rationalism presupposes knowledge as a logical extension of a transcendental category in the field of experience, while the tradition of empiricism presupposes the interaction of experience between humans and the world. The transcendental presupposition of rationalism was questioned by the scientism; empiricism lost its natural necessity after Hume's Three Questions (Russell, 1948/2001).

Since the end of the 19th century and the beginning of the 20th century, psychologists began to participate in the study of epistemological problems, hoping to explain "how people acquire knowledge" and "how people learn" through the strategy of "scientific psychology". However, most of these works do not go beyond the philosophical category of rationalism or empiricism, and only make the phenomenological description of the problem of human cognition under the presupposition of a certain meta-theory (Leahey, 2013; Jiang, 2018). Comparing with such works, Piaget took a different approach and opened up a constructive epistemology path beyond rationalism and empiricism. Piaget's work is obviously beyond the ordinary meaning of psychological research, and establish a system of thoughts on the level of meta-theory, creating a new epistemology —— The GE. Piaget is often referred to as a philosopher, but he firmly defines his epistemology as a science (Piaget, 1972/1981). From the beginning of his theoretical construction, Piaget took a different approach from the classical epistemology and psychology, which was called Jean Piaget's structuralism.

Piaget's work on structuralism, in fact, gave a great impetus to the structuralism movement in the mid to late 20th century.

Piaget was instrumental in making the word "structure" popular in psychology. Any book on developmental psychology these days is fashionable to talk about "cognitive structure." In *Structuralism*, Piaget's classic exposition of structuralism methodology, he gives a classic summary of the three characteristics of "structure": wholeness, transferability and self-adjust. It is not too much to see Piaget as the standard bearer of the structuralism. (Li, Vonèche, 2000)

Piaget's structuralism gained a reputation in the fields of literature, art, sociology and philosophy, and enabled other types of structuralism to be "superimposed upon Piaget's operational structuralism" (Li, Vonèche, 2000). Piaget's structuralism is able to assume this role because it is "both a methodology and a philosophical epistemology" (Li, Vonèche, 2000).

Piaget's epistemology is the sublation of Immanuel Kant's transcendental category theory. He inherits Kant's category theory, abandons his transcendentalism, and provides a genetic explanation of category with "sensori-motion coordination" (Xiong, 2002). According to Kant's category theory, the understanding without the perceptual material is empty, and at the same time, the perceptual material without intellectual processing has no cognitive meaning. The Category is the foundational prescriptivity of cognition, which defines the way in which perceptual materials are "structured" (Kant, 1781/2004). Therefore, the process of cognition seems to be described as a "process of structuralization based on some structure". The structure here is both the premise and the result of cognition. This is what is called structural-based epistemology.

Similar ideas have found their way into many schools of psychology, such as structuralism, gestalt, and current approaches to cognition and cognitive neuroscience. Such structural epistemology is either moving towards *a priorism*, such as Chomsky's innate grammatical hypothesis, or towards reductionism, such as cognitive neuroscience, which views neurophysiological structures as necessary premises for mental processes. In response, Piaget criticizes: "The structure they want has no history, no process, no function, and no relation to the subject" (Piaget, 1979/2007, p. 46). This means that what Piaget refers to as "structure" should be historical, genetic, subject-object construction, and is to serve some function. It is precise because Piaget's "structure" has these characteristics that his structural theory has methodological significance.

Piaget established structuralism as a methodology by defining the three characteristics of the structure. The three characteristics are: wholeness, transferability and self-adjustment (Piaget, 1979/2007, p. 4~6).

Wholeness

When we say that structure is a system of wholeness, we mean: (1) that it has a boundary between inner and outer; (2) that it is made up of a number of components, and that these components are bound together by some law (Piaget, 1979/2007).

A structure has a boundary between the inside and outside, which means that each structure has its own relative independence, and there is a possible interaction between structures. And the internal components of the structure also need to be connected as a whole according to some rules. Between structures, we can get knowledge about one structure through another one; in one structure, we can get knowledge about one component through another one. This activity is an operation. According to different ways of operation, the structure "between" and the structure "inside" of a variety of organizational forms are constructed, such as "group", "groupment" (grouping), "lattice" and so on[2]. According to Piaget, these organizational forms are "logical-mathematical structures" (Piaget, 1949/1972). The structure itself has different levels and different organizational forms. When different levels and different forms of the structure interact with one another, it cannot be static, and thus historical and genetic.

Transferability

The structure in Piaget's theory is not a static "form" but "some system of transformations" (Piaget, 1979/2007, p. 8). The well-known INRC group is a group composed of a set of basic logical operations, including direct operation, inverse operation, reciprocal operation, the identical operation, etc. This set of basic logical operations constitutes the transformation system that can be derived from almost all human thinking forms, such as 16 binary operations, 256 ternary operations, and 65536 quaternary operations (Piaget, 1952). It is these forms of operation and the rules that govern them that constitute the structure itself. This structure is what Piaget calls "logic".

It should be pointed out that Piaget's logic is not the logic of the traditional logicians "to establish rules for human thinking", but the "description of how people think". Classical logic is actually an artificial invention of logicians, while Piaget's logic is a formal description of the development of children's cognitive ability from birth to maturity, and a formal representation of all human knowledge. The most basic cognitive categories, such as motion, time, and space, can be expressed as a series of logical-mathematical operations (Piaget, 1955; Piaget, 1949/1972).

The transformational nature of the structure once again emphasizes the developmental nature of Piaget's structure. The operations contained in the INRC group can be transformed and replaced with each other; that is to say, starting from any kind of operation, after several transformations, it can return to the original starting point again. Therefore, such conversions are circular. However, every time child goes through a loop, the level of operation goes up to one higher level. In such a spiral cycle, the operation structure can be developed, and children's cognitive level has also undergone a leap.

Self-adjustment

The self-adjustment of the structure makes it conservative and relatively closed, which means that "the transformations inherent in a structure do not go beyond the boundaries of the structure, but only produce elements that always belong to the structure and preserve the laws of the structure" (Piaget, 1979/2007, p. 10). When a structure is conserved and closed, it is in equilibrium. Self-adjustment is the possibility of a structure maintaining its equilibrium. Every de-equilibration of a structure requires self-regulation to restore the equilibrium. "Operation is the 'perfect' adjustment" (Piaget, 1979/2007, p. 11). Through the operational adjustment, children's cognitive structure develops from sensori-motor coordination to formal operation. Because of this self-adjustment, the structure is historic. It is in the historical process of structure that human's knowledge is formed and realized formalization.

From the above features, Piaget's structuralism answers the question of the development of the structure.

If people "regard structure as the product of subjective reason, project it to the object, and then achieve the harmony and correspondence between the subjective and objective" (Li, Vonèche, 2000), it is inevitable to encounter the problem of how the structure comes into being or originates. In other words, when the structure is treated as an object, there must be a subject responsible for it. When we cannot find such a subject in reality, transcendentalism becomes the inevitable choice. It is for this reason that Kant, Chomsky and others have made *a priori* presupposition to the structure. Unlike such kinds of structuralism, Piaget's structure does not exist as an object of a subject, but as a construction of interaction between subject and object. In other words, the structure appears only when the subject and object interact, whereas structure appears precisely because of the interaction between subject and object. For example, when a baby pulls on a rope and hears a bell, this interaction between subject and object forms the structure of the child's initial sensori-motor coordination. Through this kind of genetic interpretation, Piaget's structure has a starting point that does not depend on transcendentalism. Therefore, Piaget's "structuralism" is a kind of structure-constructivism: The structure in the sense of Piaget is both historical and constructive. The constructive process of the structure is both a process and a method.

To sum up, the "construction" in Piaget's structuralism is firstly the interaction between subject and object, which me-

[2] Owing to space constraints, the implications and interrelationships of this set of concepts are not covered in this paper, but are discussed in detail elsewhere. The same is true of the INRC group referred to below.

ans “adaptation”, and adaptation is the “function” of the organism, which is the logical starting point of the genetic construction of the structure. So Piaget’s discussion starts with “structure” and ends with “function”. Therefore, structuralism is not the ultimate goal of Piaget. He thought that structure is only the expression of function, which is the fundamental attribute of the activities of organisms and the starting point of knowledge and intelligence. The structure serves the implementation of the function; that is, there is a structure because there is a function: “In my terminology system... the formula ‘function creates organs’ is not only correct at the phenotype level... The phenotype modifies the internal environment, and it is the resulting new framework that selectively controls the genetic variation produced in the unbalanced situation” (Piaget, 1976/1978). That is to say, the regulation and reconstruction of DNA structure or mental operational structure are to realize some function, and thus to realize the re-equilibration with the environment (Piaget, 1974/1980). In this way, Piaget established the logical pre-existence of function relative to structure, and provided a logical starting point of occurrence for structure. It can be seen that Piaget’s structuralism differs from the views of others structuralism in the 20th century on the relationship between function and structure. Piaget did not set structure as the logical starting point of epistemology; he pointed out that it inevitably leads to transcendentalism, such as Chomsky’s innate language mechanism (Piaget, 1979/2007). Self-sufficiency is possible only when the structure serves its function. The self-sufficiency of structure comes from the generative construction of function. So Piaget’s structuralism is also a kind of functionalism.

When we speak of Piaget holding some kind of functionalism, we must not confuse Piaget’s account of function with James’s “functionalism”. What James calls “function” is logically attached to the bodily activities of organisms, so James’s functionalism is, in fact, reductionism, which is not essentially free from the trap of dualism (Jiang, 2018). It is only by putting function as opposed to structure in the logical first place that we will be able to solve the problem of mind-body dualism (Jiang, 2016). By defining the functional-structural relationship, Piaget transcends the dualism or reductionism of mainstream psychology and expresses a vision of mind-body unity. This is also the goal of Piaget’s GE.

3 Method of thinking: A dialectic transcending reciprocal proof

Les Formes él Émentaires de la Dialectique was published in October 1980. Jean Piaget died on September 18 of that year. In this book, Piaget had reported that he and his colleagues explored the development of children’s dialectical thinking in more than ten tasks such as “objects identification”, “time and space”, “sequences of numbers”, “interpersonal relationships”, and “incomprehensible relations”. As in previous studies, Piaget also described the children’s cognitive development order in the stage of pre-operation (stage I, 4-7 years), concrete operation (Stage II, 8-11 years) and formal operation (stage III, 11, 12 years), each of which is divided into A and B levels.

According to Piaget, the logic of children expressed in three core ways of thinking of human beings: deduction, induction and dialectics. Among them, deductive and inductive methods in the Western academic tradition has been fully discussed. Piaget criticized deduction and induction through constructivism, and established dialectics as the genetic basis of cognition. It is because of the difference in thinking methods that Piaget’s GE should not be classified as psychology in general and philosophical epistemology in the traditional sense.

Piaget “regarded all forms of cognitive activity as dialectical, ... transcending the limitation of the method of attributing all kinds of constructions to a deduction or an inference[3]” (Piaget, 1980). Piaget found that “in all cognitive development, there are ‘inferential methods’ and ‘dialectical methods’ alternating, and ‘inferential methods’ are often contradicted by a lack of careful analysis and good definition”. At this point, a dialectical approach is essential to overcoming such difficulties (Piaget, 1980). Piaget criticizes the reliance of deductive methods on axioms as ultimately leading to transcendentalism, and also criticizes the lack of necessity of inductive (i.e., “inferential”) methods. He chose the dialectics realized in the interactive construction of subject and object. Through the study of children’s dialectical thinking, Piaget reveals the indispensable role of dialectics in children’s new knowledge acquisition and the formation of the new cognitive scheme.

It is necessary to point out that Piaget’s dialectics is the transcendence and development of Hegel’s dialectics of “The positive and negative”. Hegel achieves the unity of opposites through three propositions of “positive, negative and synthesis”; that is, any existence contains its opposite, which can be expressed as follows:

$$A \rightarrow \overline{A}$$

The unification of the two sides of the contradiction is the implication of mutual proof and the transcendence of the law of contradiction of the classical formal logic. It is as if a cookie had been broken in half, and we can confirm the existence of the other half based on either half, and know the shape of the other half based on the shape of the other half. This kind of inference is inevitable, and is the synthesis unification of the main topic and the anti-topic. Thus, we can form a comprehensive proposition with inevitability at a higher level. Therefore, Hegel stressed that “only through the principles of dialectics, the scientific content can achieve the internal connection and inevitability” (Hegel, 1817/1980).

Hegel’s dialectics is Idealism (Xia, 2019). On the basis of Hegel’s dialectics, Marxism discussed “the definition of dialectics in the epistemological horizon” and “the definition of dialectics in the existential horizon”, and achieved a double inversion of Hegel’s dialectics: the inversion of the relation between idea and reality and the inversion of the relation between motion and speculation, thus creatively realizing the materialism dialectics. The Materialist Dialectics, on the one hand, returns activity to the object world, and, on the other hand, responds to the possibility of motion based on the object (Xia, 2019).

Piaget inherited Marxism’s Materialist Dialectics, and critique of rationalism or transcendentalism and developed the field of occurrence of dialectical relations. Piaget’s dialectic is not merely reciprocal, but can occur between any two separate systems. They do not have to be mutually exclusive. When they merge and produce a new system, the nature of which goes beyond the original system, this is dialectics. Therefore,

[3] It’s a means of induction.

the core meaning of Piaget's dialectics is not the unity of opposites, but the coordination and confirmation of two independent parties. This kind of confirmation generates new knowledge. Therefore, Piaget's dialectics is a kind of "generative" confirmation, which is the starting point of the new system (Piaget, 1980).

D'après Piaget, il y a dialectique lorsque deux systèmes, considérés jusqu'alors indépendants, entrent an interrelation et s'intègrent à "une totalité nouvelle dont las propriétés les dépassent". La façon dont les intégrations réussissent présentent les caractéritiques fondamentales suivantes:

a) les concepts et notions intrinsèques aux sous-systèmes à partir desquels la nouvelle totalité sera construite passent par un processus de "relativisiation";

b) la contruction de nouvelle totalités (ou structures) implique un certain processus circulaire (ou plus précisément, une trajectoire en spirale) dans la mesure où elle nécessite des "remanirements rétroactifs enrichissant les formes antérieures du système considéré". [4]

For example, a baby lying in a crib can see a bell hanging from it, and his hand can pull a dangling rope. These are two separate events — perception and action. When the child pulls on the rope and hears the bell ring. The two events are in coordination. The result of coordination is a relationship between the two events. This process is a dialectical construction; that is, two independent events merge to produce a new system. On the basis of this coordination, children further abstract the relationship, which is the reflective abstraction. Reflective abstraction is a dialectical construction based on the coordination of primary perception and motion. As stated earlier, reflexive abstraction is the return from the experience to the cognitive scheme, so, after reflexive abstraction, logical operations complete a cycle. This is the characteristic that dialectical logical operation is different from the deductive method and inductive method. The deductive method does top-down operations from axioms and the inductive method does bottom-up operations from experience. Both operations are linear, starting from one point and pointing in the other direction. The operations of the dialectic form a loop, such as the INRC group. However, such cycles are developmental, and Piaget's distinction between the stages of children's cognitive development is based on the kind of circular operation that complete reciprocal operation in the INRC group can be realized when children reach the concrete operational stage.

Based on the INRC group, Piaget derived 16 binary operations and 256 ternary operations (Piaget, 1952). It can be said that Piaget expressed a systematic system of dialectical logic through the writing of these formulas.

Rolant Garsia had written the postscript for *The Basic Forms of Dialectic*, he said, these efforts "aim to separate Piaget's thought from traditional dialectics, or more precisely, from the traditional school that originated in Hegel and the Marxist". He regards Piaget's dialectics as the "fourth kind" of dialectics, which is different from Hegel's and Marxism's dialectics and Post-Marxism's application of dialectics in sociology and politics. Garcia also expressed concern about the future of Piaget's dialectic, he writing as:

Les philosophes classiques n'avaient pas soupçinné que les analyses à la fois sociogénétiques et psychogénétiques pouvait résulter une théorie de la connaissance bien établie et cohérente. Il n'était pas non plus reconnu à la dialectique un rôle intrinsèque dans la théorie de la connaissance, dans la mesure où le processus cognitif ne peut être conçu que comme une série d'autre que le dépassement d'une situation conflicturelle. (Piaget, 1980)

Although Piaget's original intention is to let the category theory get rid of Kant's *priorism* and try to construct a kind of generative category theory, "Piaget was like a child playing on the beach, constantly drawn away by the beauty of the shell, forgetting the way home" (Li, Vonèche, 2000). That is to say, Piaget set out from the category theory, and hope to verify the occurrence of each category by means of empirical research. But in the course of his research, new discoveries were made, which led him to conduct further research, and eventually, he fell further and further away from the original categorical starting point.

However, we see that Piaget's dialectic attacks deduction on the one hand, and induction on the other. When Piaget criticizes both, he inadvertently shows the effect of Kant's philosophy. Kant emphasized that knowledge can only be formed through the combination of experiential materials and transcendental categories. Piaget's dialectics also forms new knowledge through the combination of two systems: perception information system from experience and body action system from heredity (Piaget, 1980). It could be looked as the tribute to Immanuel Kant by Jean Piaget in his later years.

4 Research Methods: The clinical interview method priming the psychological qualitative research

Piaget's research method is called the "clinical interview method", also known as the "Geneva exploration technique". This is a method derived from psychoanalytic talk therapy and Alfred Binet's intelligence test (Zhang, Luo, 2019; Zhang, Zhang, 2007; Zhang, Liu, 1998; Lu, 1983; Cao, 1962). Piaget provided children with devices and props such as scales, levers, weights, plasticine, building blocks, and asked them to perform certain tasks on the device, such as balancing the scales, or predicting or judging the consequences of running the device, for example, if one end of the lever moves, what happens at the other end, or if a lump of plasticine is changed from a ball to a strip, does the overall mass increase or decrease. During this process, he asks the child questions and records the child's answers, including actions and soliloquies. According to Piaget, these patterns reflect the logic of children's thinking at certain cognitive levels. In contrast to the psychoanalytic method of conversation, Piaget's "clinical interview" created tasks for children to answer questions by coordinating their actions with their language; unlike psychoanalysis, which allows the patient to make free associations entirely in speech; clinical interviewing requires more than just a yes or no answer, compared with Binet's intelligence test, and further guides the children to explain "why this is so". It is in these interpretations of children that Piaget abstracts out the features of the child's mind. Therefore, Piaget's "clinical interview" is actually the research method of "loud thinking". For example, to examine how children categorize nested relationships, Piaget presented children with a series of 18 cards, nine of which were large and nine of which were small, di-

[4]See Roland Garcia's postscript for *The Basic Forms of Dialectics* (Piaget, 1980).

vided into three shapes: three squares, three circles and three rectangles; on another dimension, there are three colors: six are brown, six are blue, and six are white. Three colors, three shapes and two sizes make up 18 combinations. Here is Piaget's conversation with a child (with Piaget's words in bold):

ANA(7;6) **suppose en I que la figure à trouver est le grand carré brun, mais sans certitude (jeton à 1/3)** parce que "c'est ça (grand rond brun) ou ça (grand carré). --- **Si je te dis qu'il est grand tu deviens plus sûre?** --- Non, je crois que c'est ça (grand carré brun). --- **Tu es plus sûre?** --- Oui (jeton à 5/6: or elle disait déjà qu'il est grand). --- **Si je te dis encore qu'il carré?** --- Alors sûre (jeton à l'extrême droite). --- **Ça pourrait enêtre un autre?** --- Non (or il reste qu'il pourrait être bleu ou blanc, ce qu'elle n'infère pas). --- **Tu sais 2 choses: grand et carré. Combian y en a-t-il?** --- Oui.--- **Sûre?** --- (Jetonà l'extrême.) --- **Je dis encore qu'il est bleu.** --- C'est ça (grand carré bleu, donc juste). --- **Sûre?** --- Tout à fait". (Piaget, 1980)

In this way, Piaget examines the formation and development of children's logical thinking. Piaget argued that the development of logical thinking in early childhood is not amenable to experimental investigation. Because the logic he examines is not a fait accompli but is constructed in activity, the researcher, unlike the classical experimental study of psychology, cannot form hypotheses according to some kind of fait accompli logic. The hypothesis is verified by precisely controlled and closed experiments. Piaget's study is an open-ended process of abstracting a child's logic from the content of their conversation.

On the one hand, some psychologists do not accept the scientific nature of clinical interviews, arguing that such methods lack sufficient precision and quantitative analysis, and do not avoid the researchers' preconceived induction of children's responses. Philosophers or logicians, on the other hand, argue that the principles derived from interviews are too empirical and too far removed from the speculative metaphysical strategies to which philosophers are accustomed (Zhang, Li, 2019). Although Piaget developed a highly formalized mathematical representation of children's thinking through interviews, he developed several mathematical logic formulas. However, Piaget's formula does not have the same logical meaning as the traditional mathematical logic formula, and there are differences in the way it is deduced. The logician's logical formula excludes the actual content of thinking and is a completely abstract and formal representation of the thinking process. Piaget's logic, on the other hand, is a "logic towards meaning", a psycho-logic (Ricci, 1987). Piaget's psycho-logic was difficult to be accepted by the mathematical logicians who were in vogue in the mid-20th century.

Despite criticism of the scientific nature of Piaget's research methods, psychologists have unreservedly accepted his theory of stages of cognitive development of children. This contradiction reflects the psychologist's own anxiety about scientific nature. Because psychology itself is being questioned by scientists, and because the objects of study in psychology cannot meet the standards of natural science, it seems that the minimum guarantee for the scientific nature of psychology can only come from the limitation of research methods. Within the academic world of psychology, it is common to see academic groups debating research methods most of the time. It seems that as long as experiments rely on enough equipment and advanced statistical techniques, the scientific nature of psychological research is assured.

Karl Popper proposed that the significance of science lies in the open hypothesis and objective and fair test, which is the "falsifiability" of science. Only under the guidance of the correct idea about science can we form a rational attitude about the research methods of psychology. One example is the qualitative approach that has gradually gained acceptance in psychology in recent years. Qualitative research techniques have shown more accurate problem-orientation than quantitative research in exploring some complex issues, such as individual psychological experience in complex social relationships. The scientific nature of qualitative research technology has also been more and more widely recognized. In fact, in the study of cognitive psychology, "thinking aloud" is a special paradigm of qualitative research technique. In the study, the subjects reported their own thought processes actively, which is still an effective way of thinking activities that are difficult to explore through objectification techniques. By talking to children, Piaget is actually leading them to think aloud in response. As a result, Piaget was an early pioneer in applying qualitative research techniques to the field of psychology.

5 Scientific epistemology: GE deal the difficult problem of psychology

Next, Piaget demonstrates the scientific significance of GE through the methodological distinction.

Piaget first questioned the epistemological significance of philosophical "insight". He pointed out that, "philosophy provides a framework for the sciences such as logic, psychology, and sociology, relative to other systems, but when we encounter it in mathematics and science, it provides us with 'wisdom' rather than knowledge on the practical level of access to words" (Piaget, 1965/1971). The reason why philosophical epistemology cannot provide knowledge is that they adopt the top-down deductive method, or "axiomatic method". When we adopt the axiomatic method, it means that we must admit the *a priori* knowledge, because if we do not resort to "divine revelation" or *a priori* knowledge, the legitimacy of the axiom itself cannot be confirmed. Therefore, the axiomatic approach does not actually provide us with new knowledge. Every deduction from the axiom is a kind of thinking operation. In this sense, the axiomatic method reflects the activity of "wisdom".

When it comes to science, Piaget said, "there can be many kinds of wisdom, but the truth is the only one" (Piaget, 1965/1971), that is to say, the knowledge corresponding to wisdom as truth is formed in science. "When knowledge is imposed on every individual for definite reasons," Piaget wrote, "it becomes immediately scientific, and no longer philosophical" (Piaget, 1965/1971); that is, as opposed to the diversity, metaphor, and relativism of philosophical wisdom, scientific knowledge is unique, specific, and compulsory. But Piaget also points out that the bottom-up approach to empiricism (what in Piaget's context calls the "inferential" approach, the "inductive" approach) fails to capture the inevitability of knowledge.

Through his critique of transcendentalism and empiricism, Piaget initiated a discussion of the meaning of science. Literally, Piaget agreed with Russell's definition of science: "All exact knowledge belongs to science" (Russell, 1946/2004, p. 11), but on the level of "the value of science", he criticized

Poincaré and Gestalt[5], then expressed their scientific view: we should say the meaning of scientific knowledge in the historical and developing process in the corresponding sense of man as the cognitive subject and the world as the object. These discussions ultimately boil down to Piaget's constructivism that the generative process of scientific knowledge is not deductive from axiomatic theory or inductive from empiricism, but constructive. Only constructive genetic epistemology can not only ensure the necessity of scientific knowledge, but also get rid of the limitations of transcendentalism to trace the starting point of knowledge. Therefore, epistemology is necessarily the epistemology of science, and vice versa, without science there would be no true epistemology, "if a system has nothing to do with science, it will not effectively form the initial epistemology and will be limited to the interpretation and justification of values" (Piaget, 1965/1971).

It is by demonstrating the scientific significance of genetic epistemology that Piaget's methodology removes a major obstacle to the scientific dilemma of contemporary psychology.

Since Descartes, psychology had been cursed of not being science (Leahey, 2013). Classic scientism questions the scientific nature of psychology with the question of objectivity. The classical scientism holds that the foundation of objectivity is the presupposition of the object-object relationship in scientific research; that is, the researcher, as an absolute bystander, will not interfere with the interaction between the objects in scientific research; no matter who the observer is, the "object-object relationship" between the objects will not change; scientific knowledge is the objective reality existing in the object-object system, waiting for people to discover it. The scientist's job is to progressively abstract general principles from observations of the object-object system. It is this process of knowledge discovery that underpins the objectivity of science. The research object of psychology is not the pure object-object relationship, but the interaction between the subject and the external object, that constitute the subject-object relationship. Because "psychology" cannot be directly observed and measured from a bystander's perspective, the experience of "mind" can only come from the subject's own insight. The so-called "mind" can only be reflected in the relationship between the subject and the object. The cancellation of behaviorism, the reduction of cognitive neuroscience, and so on, are through efforts to eliminate the subject-object relationship to ensure the objectivity of psychological research. However, is the subject-object relationship the real obstacle to the study of objectivity in psychology? Can natural science only study the pure object-object relationship, but not be compatible with the subject-object relationship?

GE deconstructs the pre-supposition of the relation between subject and object of classical scientism, making the relation between subject and object the golden-standard of science. In Piaget's structure-constructivism, the "subject" as an observer and the "object" as being observed is no longer completely separated, but scientific knowledge is formed in the interaction between the subject and the object. The object of scientific study is, in fact, some events occurring in the subject-object relationship (Piaget & Lévi-Strauss, 1984). It is not an objective existence independent of man, but an interactive construction between man and the object world. Finally, in his three-volume *Introduction to Genetic Epistemology* (*Introduction l'Epistémologie Génétique*. Tomes 1~3.), Piaget completed the work of integrating mathematics, physics, biology, psychology and sociology into GE. This work demonstrates how scientific knowledge comes into being in the subject-object relationship. In this work, we can see Piaget's inheritance and transcendence of Poincaré's "*The Value of Science*" (1913/2007). Piaget systematically elaborates on his "historical view of the genetic science". Before Piaget, Husserl used phenomenological analysis to demonstrate the fundamental significance of the subject-object relationship in scientific research (Husserl, 1965/2007). Piaget's subject-object relationship was also an inheritance and transcendence of Edmund Husserl (Piaget, 1965/1971). Piaget's work later inspired the "paradigm" expressed by Thomas Kuhn of his *The Structure of the Scientific Revolution* (Ye, 2006). Till today, the scientific meaning of the subject-object relationship has not been fully accepted by the naturalist, but it has been extended from Poincaré and Husserl to Piaget and then to Kuhn. Their efforts are, in fact, contributing to the gradual evolution of the concept of the history of science.

By redefining the meaning of science, Piaget dispelled an important obstacle in the approach science of psychology. The subject-object relationship is no longer the limitation that perplexes the objectivity of psychological research. Objectivity comes from the standardization of research methods rather than the types of research topics.

From the aspect of psychology itself, constructivism takes "adaptation" and "coordination" as the ontological presupposition, which opens a possible way for the unification of mind and body in contemporary psychology.

Mind-body dualism is another fundamental obstacle in the way of scientific psychology. Since Wilhelm Wundt, generations of psychologists have tried to find a way to bridge the gap between mind and body. Psychology was founded three times in its history: Wundt founded the psychology of consciousness, Freud founded the psychology of unconscious mind, and James founded the psychology of adaptation. Among them, adaptive psychology is "the most valuable and influential in academic psychology", and gave birth to today's mainstream of psychological theory such as functionalism, behaviorism, cognitivism and evolutionary psychology (Gao, Yang, 2011). Much of the work of adaptive psychology, especially evolutionary psychology today, provides a possible way to explain how psychology arises and develops from organisms. One could argue that this is a possible mind-body unification strategy (Jiang, 2018).

The thinking behind adaptive psychology is Darwin's theory of biological evolution. While Darwin's theory of evolution offers a possible explanatory vision for psychology, it also throws psychology into a "trap" of mind-body paradoxes. Because Darwin's theory of evolution is a "theory of biological evolution," it is "logical transgression to extend the theory of evolution as the cornerstone of psychological thought" (Gao & Yang, 2011). From the perspective of cybernetics, the core of evolution is "adaptation"; that is, the process of biological evolution can be realized, there must be some connection and interaction between organisms and the environment.

[5] Piaget's works have one characteristic: the theory he quoted most is also his most critical, at the same time, it has the greatest influence on his own theoretical construction. Bergson, Russell, Poincaré and Gestalt are frequently cited in Piaget's works. It is through the criticism and transcendence of these people's theories that he constructed his own theory.

This connection and interaction is adaptation. Natural selection, as described by Darwin's theory of evolution, is a completely random process in which there is no necessary connection between organisms and environmental selection. Thus, Darwin's theory of evolution lacks a true sense of "adaptation". That's what Piaget's critique of Darwinism is all about. As mentioned above, evolution is one of the meta-theories of GE. Of the many theories of evolution, Piaget followed Bergson's "Creative Evolution", which had something to do with the influence of Bergson's writings in his youth (Piaget, 19651971). The Creative Evolution emphasizes the active effort of an organism's choice in the process of evolution, and defines the interaction between organism and environment as "adaptation" as the driving force of evolution (Piaget, 1976/1978). Using the concepts of "phenocopy" in the biological sense and "reflective abstraction" in the psychological sense, Piaget established an interactive relationship between the physiological, psychological and environmental effects of an organism, avoiding the logical paradoxes of Darwinism and Neo-Darwinism about "adaptation". Only in this way can GE become an effective strategy to achieve the unification of mind and body.

The counterargument would be that Creative Evolution describes a purposeful evolutionary process (Bergson, 2004). This purposefulness causes the organism to "actively" adjust its genotype to fit the effect of the environment. One of the most controversial is the "if acquired experience can be inherited". Although Piaget offers some explanation, most scientists prefer the theory of "natural selection" based on random variation and probabilistic selection until there is clear biological evidence to support it.

In response, biology's search for the "epigenetics" has never been interrupted. Since the 1950s and 1960s, there has been sporadic evidence that environmental influences influence the transcription of DNA (Piaget, 1989; 1979/2007). In 2019, *Cell* published two works of Posner et al. (2019) and Moore et al. (2019). They both found that nematodes can pass on individual memories via RNA to their offspring (Posner et al., 2019; Moore, Kaletsky & Murphy, 2019). This is evidence of the "heritable acquired experience". Although the researchers say that this phenomenon is only found in organisms as simple as nematodes, there is no evidence that memory inheritance is possible in human beings. However, we can expect that further biological evidence to support the hypothesis of phenocopy. It may not be too far away.

In addition to solving the problem of how settling psychology down, Piaget's methodology also provides some possible solutions to many medium level psychological "difficult problems".

The first is the problem of induction. It was not until the 20th century, after David Hume, that philosophers finally recognized the impossibility of establishing a unified inductive logic (Russell, 1948/2001); the psychological study of inductive reasoning has been going on for more than half a century, but, in addition to describing phenomena, the existing research has not formed the "explanatory" theory or model. Because induction involves "the acquisition of new knowledge", "the formation of concept" and so on, these questions are "difficult problems" in the study of mind or consciousness. GE gives an answer to such questions, answering the question of how newborn babies start from zero experience to building a knowledge system about the world. In the framework of GE, Piaget systematically studies the formation of children's basic cognitive categories such as "time", "space", "force" and "speed". These research methods and conclusions are still excellent examples and theoretical foundations for us to continue to explore these issues today. We still need to address these issues in the framework of GE today.

The second is "other minds problem". This is another difficult problem in the study of the mind. Descartes uses "Cogito Ergo Sum" to demonstrate the existence of "self", but also leaves behind a "unique mental paradox". Therefore, the problem of "other mind" has become another "difficult problem" that perplexes philosophers and psychologists. In the fields of psychology and neuroscience, although a series of studies have been carried out around the theory of mind and found that the mirror neuron was the neural basis of other mind cognition, these studies cannot go beyond the description of the phenomenon to make a real "explanation" of other mind problem without epistemology as a meta-theory. Other mind problems also gave rise to "animal mental problems", "robot mental problems" and so on. Taking the coordination of perception and movement as the starting point, GE describes the process of constructing the equilibration of children's minds from the inner subject to the inner subject. This pattern could also be used to explain the mental construction between human-human, human-animal, and human-robot.

The third is the problem of mental calculation and embodied cognition. From the 1950s to the 1960s, computational cognitivism and cognitive neuroscience, with the help of computer science and neurobiology respectively, have occupied the theoretical space of mind research. Therefore, the meta-theoretical significance of constructivism and GE to cognitive science has been neglected.

Although Piaget had put forward a system of logic, his logic had different meanings from the classical logic. Piaget's logic is not a norm, but a fact, or "normative fact" (Piaget, 1963/1995; Smith, 2006); Piaget's "operation" is also different from the "computation" of computational cognitivism. Piaget's operation means the coordination of perception and motion. This assumption was criticized by the computational cognitivism prevailing in the 1970s and 1980s[6]. Computational cognitivism holds that the logic of the mind should follow the classical rules of mathematical logic and should be an abstract setting that can be separated from bodily movements. This assumption of Computational Cognitivism, coupled with the engineering needs of computer science and artificial intelligence, left Piaget's concept of logical operation being ignored.

With the rise of "the second generation of cognitive science", computational cognitivism no longer hold its absolute speaking right (Li, 2008), and the reductionist presupposition of cognitive neuroscience has been challenged (Jiang, 2017). Correspondingly, the hypothesis that thinking is action is supported by empirical research from the field of embodied cognition. Since the 1990s, the study of embodied cognition has become more and more popular. "Back to the body" and "thinking with the body" are the logical extension of Piaget's sensori-motor theory (Ye, 2010, 2019).

In short, the ideas of Piaget that have been criticized in the

[6] See the response of Campbell and Bickhard (1987) to Fodor's anti-constructivism.

21st century are increasingly backed up by new scientific research. In this sense, Piaget's theory is forward-looking. However, as a meta-theory of psychology, it still has a long way to go before it can be fully understood and accepted by scientists. To this, Piaget had shown great tolerance and patience:

It is perfectly legitimate for the philosopher to feel the need to concern himself with the limits of science, but on two conditions: not to overlook those of philosophy and to remember that science, being essentially "open", these known limits are always the present one. (Piaget, 1965/1971).

6 Conclusion

A decade ago, in an essay commemorating the 30th anniversary of Jean Piaget's death, Li Qiwei had lamented the "obsolescence" of Piaget's theory as the study of Piaget waned (Li, 2010).

Is Jean Piaget's theory really out of date?

Throughout the history of human thought, we can find the phenomenon that countless classical theories have gone up and down in the course of thousands of years, sometimes welcomed and sometimes ignored, but never "out of date". It is interpreted and annotated in different ways by contemporary people. A theory is judged to be truly "obsolete" only for two reasons: first, the theory itself has been falsified; second, the theory has been "perfected". There is no need for follow-up studies to supplement and revise them. The second reason is impossible for a strict scientific theory. A scientific theory can never reach absolute "perfection". Moreover, there did be some theories in history which were once considered as a science, but then being "out of date" for the first reason, such as the heliocentric theory of astronomy, the phlogiston theory of chemistry, the ether theory of physics, and so on (Kuhn, 1962/2004).

According to this criterion, it is not difficult to find that Piaget's GE is not "out of date"; on the contrary, it is showing the guiding value of current psychological theoretical and practical research, for example, the definition of the stages of children's cognitive development is still the norm in developmental psychology. Similarly, psychoanalytic theory, behaviorism, and so on, are classic theories in the history of psychology that have never been out of date, but whose main concepts are no longer the central vocabulary of current mainstream discourse in psychology, or, emerging research technologies have led to a number of new research topics, and so far have not found a combination of classical theory. Therefore, the classical theory may no longer occupy the central position of the current mainstream discourse, but in fact, the current hot topics are not out of the scope of these classical theories. For example, the current study of embodied cognition is, in a sense, a translation and paraphrase of the theory of sensori-motor coordination in another terminology system.

Today, although Piaget and his GE are somewhat "lonely after death", his theory is still worth continuing to be studied, understood and developed.

We have full reasons to expect a "rediscovery of Jean Piaget".

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