Nature Vs. Nurture: Is the Origin of Logic Innate or Acquired

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Abstract. The study of logic since 5 BCE has given rise to various logical systems, such as theological, classical, and intuitionistic. There are applications in various fields such as semantics and philosophy. The question of whether logic is inherent or acquired through experience has long been debated by rationalists and empiricists. This research aims to elaborate on the long-lasting debate about the innate nature of logic through exploring fields such as neuroscience and psychology. Logical reasoning is a crucial cognitive skill, enabling critical thinking, problem-solving, and decision-making in everyday life, academics, and professional settings. Professor Justin Halberda and Dr. Nicolo Cesana-Arlotti done experiments recently focusing on disjunction syllogism logic in infants below 2 years old. The experiment observes the external behaviors of the babies, an indirect method to evaluate the thoughts and mind of the babies. The conclusions of the experiments indicated that infants seemed to engage in logical inference conspicuously during ambiguous situations, implying the existence of some basic logic models from birth.

Keywords: Logic; Innate Ability; Acquired Potential.

1. Introduction

Logic is the systematic study of reasoning, inference, and the principles that govern valid and sound arguments. Logic acts as the bed stone of rational thinking and logic is often used to analyze and discover the relationships between statements, ideas, and concepts [1]. Logic aids one to from well-structured statements, arguments, and is closely related to the neuroscience and psychology, thus by digging deeper into this field, scientists can better comprehend the logic essence of humanity, further providing solutions to some prominent neuro-problems in the world. Cognitive development is closely related to logic since the former refers to the maturation and enhancement of mental processes, including perception, memory, problem-solving, and reasoning, which are essential components of logical thinking [2, 3]. The preciseness and complexity of logic increases and decreases along with the development of cognitive skills and obtaining experience [4].

“Innate abilities” are the abilities acquired at birth and inherent [5]. The innate attributes are often known as the “unchangeable nature” of one’s genetic component. Besides, from the aspects of the philosophers, innate could also mean universally true. An innate thing could be constantly true that everyone born to earth is able to gain this truth. In this case, rationalists (will be further discussed in this article) suggest that logic is always there, and everyone owns the ability of logical reasoning.

Comprehending whether logic is innate or not is helpful for scientists better understand the evolutionary origins of human cognitive abilities developed during the evolutionary process. It provides valuable insights for the historians, anthropologists etc. In addition, solving the problem is extremely beneficial for pedagogy. If logic is innate, educators can adapt their approach to teaching logic and critical thinking skills. Recognizing and cultivating students' innate logical abilities can lead to more effective teaching methods that align with natural cognitive processes and thus they can foster a better understanding and application of logical principles.

Logical reasoning includes deductive logic and inductive logic, and there are significant differences between them [6]. Deductive logic is the cornerstone of rational thinking from the general to the concrete [7]. It involves concluding that if the premises are true, the conclusion must be true. Deductive reasoning follows well-defined validity rules that ensure that the conclusion logically follows the premises. A classic example is the syllogism: "All men must die; Socrates is a man; Therefore, Socrates is mortal." Deductive logic excels at preserving truth, ensuring that if the premises are accurate, the conclusion must also be accurate.

Inductive logic, on the other hand, takes a different approach, from specific to general. It involves making generalizations based on observed examples. Unlike deductive reasoning, inductive conclusions are not necessarily definitive, but probabilistic. For example, after observing many white swans, one might conclude that "all swans are white." However, this conclusion is subject to revision by new evidence. Inductive logic plays a crucial role in scientific inquiry, with assumptions derived from observations, although it carries the inherent risk of drawing inaccurate generalizations due to incomplete data.

It is important to point out that logic appears in different types of forms and that the essay aims to discover whether new-born babies inherit the most basic logic models since advanced logic reasoning abilities are acquired through further studies and through understanding of the mechanism of the world, including abstract concepts such as time, space.

2. Literature Review

There are some common theories on whether logic is innate or not. Immanuel Kant, an 18th-century German philosopher, is renowned for his huge contributions to several different areas of philosophy. Among his many influential works, his views on logic have left an indelible mark on the realm of philosophical thought [7].

Kant's prominent work "Critique of Pure Reason" is a sophisticated and dense. It discusses fields including semantics, metaphysics, and the limits of human knowledge [7]. One of the key concepts he introduces is the difference between analytic and synthetic judgments. Analytical judgments are those that have predicates contained in the subject and are true, such as "all bachelors are unmarried." These analytical skills require breaking down a concept or problem into its component parts to better understand its structure and components. The process involves critical thinking and close examination. It enables humans to analyze complex ideas, identify underlying hypotheses, and reveal hidden connections. For example, understanding the components of a complex mathematical equation or breaking down the elements of an argument in a philosophical text requires strong analytical skills. Synthetic judgments, on the other hand, go beyond mere analysis of concepts and add new information to our understanding, like "the sun rises in the east." They involve integrating various parts or information to form a comprehensive understanding. This process often requires creativity and the ability to see the big picture. Synthesis allows us to combine different insights to draw new conclusions, generate innovative solutions, and form a comprehensive understanding of complex phenomena. In scientific research, for example, combining data from different experiments can yield new insights and discoveries.

According to Kant, an a priori knowledge is knowledge that is independent of experience, while a posteriori knowledge is knowledge that is derived from experience. Kant suggests that there are some judgments that are both synthetic and a priori at the same time. These judgments are key to his exploration of whether certain knowledge is innate or acquired.

In the context of logic, Kant's attitude to the question of whether logic is innate is subtle. He did not argue explicitly for the intrinsic nature of logical principles, as the rationalists did, nor did he fully accept the empiricist view that all knowledge comes from experience. Instead, he introduced the concept of a priori logic, which deals with the conditions necessary for human understanding to occur.

Kant claims that transcendental logic is concerned with the study of the a priori principles that underlie human cognition. Kant argues that these principles are not learned from experience, nor are they purely innate. Rather, they are the "rules" or "forms" that shape our experience of the world. These rules are not specific content, but rather the framework within which we organize and understand our experiences.

John Locke was a famous 17th century philosopher, well known for his philosophy and his views on the nature of human knowledge, learning, and understanding. He was an empiricist, the opposite of Immanuel Kant. Locke's empiricist stance in On Human Understanding is consistent with his broader philosophy, emphasizing the role of experience in shaping human cognition. He believed that

the mind was originally devoid of any content, and that thoughts were formed through sensory perceptions and reflections on those perceptions. Logic, as a form of abstract reasoning, is constructed through the processing and synthesis of these sensory impressions, rather than an innate ability.

3. The core debate

Various logical systems have been developed by human beings to explore different aspects of reasoning and knowledge, encompassing theological logic, intuitionistic logic, and classical logic since 5 BCE. Classical logic, which includes propositional and first-order logic (FOL), is the traditional form that focuses on valid inference and reasoning. These diverse logical systems have found applications in fields such as philosophy, mathematics, computer science, and linguistics. The origin of logic is always a controversial topic. To answer the question about whether logic is innate, it is important to review the ideas of the ancient philosophers. Immanuel Kant believed that certain fundamental concepts and categories of understanding, are innate and essential for organizing and interpreting sensory experience. Kant's view of the intrinsic aspects of logic focuses on the underlying cognitive structures and principles necessary for logical reasoning. While he does not believe that logical propositions are innate, he argues that the fundamental principles of logic that enable us to construct and understand the world have an innate basis in the structure of the human mind.

Rationalists suggests that logic is an a priori ability that one obtains when born [8]. Prominent philosophers such as Aristotle and Descartes also believed that logical truths are not contingent on experience but are universally true. One rationalist argument is based on the existence of universal concepts. For example, the concept of "identity" (A is A) seems to be universally recognized by human from different countries and cultures, suggesting that there may be an innate understanding of logical principles.

Empiricists, on the other hand, believe that logic is not an innate ability, but is derived from experience and knowledge. In The Relation of Logic to Psychology, D.G. Rich reiterates that "logic, even in its broadest sense, is concerned only with knowledge, and not with feeling and will." John Locke also concluded that humans are all born as a blank SLATE, and that one can form one's own logical model through sensory experience and subsequent learning processes. Empiricists believe that logic and reason are not reliable sources of knowledge [9].

Kant was critical of the concept of a priori concepts, particularly those advanced by rationalist philosophers such as Descartes and Leibniz. Rationalists believe that certain principles or concepts are inherent in the human mind and are the basis of knowledge. Kant, on the other hand, does not believe that we are born with specific preexisting concepts. He acknowledged that while there may be a universal structure to human cognition, this structure does not necessarily manifest itself in the form of pre-installed ideas.

Kant's position becomes clearer when he introduces the distinction between a priori and a posteriori knowledge. While Kant acknowledged the existence of a priori knowledge, he insisted that these innate structures are not concrete concepts but fundamental cognitive abilities that enable us to engage with the world and form concepts through experience. In his magnum opus Critique of Pure Reason, Kant postulates the experience of a priori knowledge, by which he means that knowledge is independent of experience. He argues that some knowledge is inherent in the structure of human cognition. In the field of transcendental knowledge, Kant introduced the concept of "intellectual category", including substance, quality, quantity and so on. According to Kant, these entities are pre-natural in the human mind, necessary even for the potential to gain experience. Although logic is not included in the list, it is closely related to them. Kant's emphasis on the transcendental nature of human cognition further supports the view of a priori logic. Because in the transcendental view, humans think rationally, which is consistent with the properties of logic.

Kant's exploration of synthetic a priori judgments is crucial in understanding his view on the innate nature of logic. A synthetic judgment involves the combination of concepts that go beyond what is already contained within them. A priori judgments are those that are known independently of

experience, through reason. Kant contends that logic is indeed a synthetic a priori discipline, and it is through this lens that we can explore its relationship to innateness.

While logic deals with valid reasoning and the rules of reasoning, Kant argues that its principles are not derived from experience but are fundamental to the structure of human cognition. These principles, such as the Law of non-contradiction, are not learned from the outside world, but are conditions that enable us to coherently construct our experience. In this sense, logic can be seen as innate because the cognitive abilities required for logical reasoning are part of the inherent structure of the human mind.

John Locke on the other hand holds a different point of view. He believed that logic is obtained through the experience and knowledge one acquired. He asserts that the laws of logic, such as the law of non-contradiction and the principle of identity, are not universally present in the mind from birth. Instead, these principles emerge as individuals engage with the external world and recognize patterns of consistency and inconsistency in their experiences.

Locke's rejection of the concept of a priori, including the principle of a priori logic, is based on his empirical methodology [10]. He emphasized the importance of observation and experimentation as how humans understand the world and develop knowledge. In his opinion, if logical principles were innate, there would be a universal agreement on them, yet differences in human understanding and cultural variations suggest that these principles are learned rather than inherent.

Furthermore, Locke's arguments against the naturality of knowledge extend to the field of mathematics, which often intersects with logic. He argued that mathematical concepts, such as geometric truths or algebraic equations, are not innate. Instead, mathematical knowledge is built on sensory experiences and cognitive processes from which individuals can abstract to arrive at mathematical concepts.

The opinions from the former philosophers are valuable and provided insights for future philosophers and research. However, an opinion is not solid enough unless there are effective proofs and experiments. Thus, this essay aims to explore the continual debate surrounding the innate nature of logic, considering various perspectives and evidence from philosophy, cognitive psychology, and neuroscience through referencing the current experiments done by researchers and scientists. A combination of ancient ideas and modern technologies will bring the problem out of the mist.

Recently, Professor Justin Halberda and Dr. Nicolo Cesana-Arlotti did an experiment just to discover whether new-born babies have disjunction syllogism model in their mind [11]. A disjunction syllogism states that if two alternatives exist and one is eliminated, the remaining alternative must take place. Moreover, logic symbols may be utilised to conveniently illustrate this. Assumption 1 asserts that A is greater than or equal to B, whereas assumption 2 states the opposite. It was either A or B, and because B was out of the question, he went with A. In their publication "Precursors of logical reasoning in preverbal human infants," published in science, the researchers describe the experiment they designed to test whether or not infants understand disjunction syllogisms.

Research focused on infants between the ages of 12 and 19 months, since this is when language and speech development typically begin in infants. Infants were offered instances where an item's identification was ambiguous but could be resolved via the use of disjunctive syllogism. Pairs of objects with different lower half but the identical upper halves were placed into the virtual theatre in Experiment 1 and Experiment 2. A sealer hides them from view, and a cup snags items from behind to only display the top halves. Using disjunctive syllogism, the baby can tell which of two things it is clutching is is is in the "latent deductive stage" when the occluder falls downward. In this "latent inference stage," newborns' brains are still developing, so they could think the dinosaur in the cup is a flower. Following the "result phase," the dinosaur is no longer there, and a new content is exposed inside the cup. Items were either consistent with or inconsistent with rational thought 50% of the time. We may conclude that the infant was shocked by the unexpected results by tracking the duration of his or her stare during the outcome phase. Baby reasoning kicks in between the ages of 12 and 19 months, as seen by the average number of views, and the child figures out what's in the cup.

Both Experiments 1 and 2 showed inconsistencies since the sealer was lowered to display the dinosaur, the creature fled the stage, and then the cup revealed the animal again. Instead, once the dinosaur went, flowers appeared in the cup on their own. Because the infant's response might be affected by superficial elements of the final order, such the identical object appearing twice, experiments 3 and 4 investigated a logical state reversal of the final item order. In these trials, the occlude was never lowered, and the object (like a snake) would withdraw, become briefly visible, and then vanish again. At the outcome stage, the cup does not expose its contents; instead, a snake or one of the other items in the pair (such as a ball) appears. Experiment 3 revealed that these babies were more engaged in the logical drive of the scenario than in the surface components of the end sequence, demonstrating that their conduct was directed by logical thinking.

These results suggest that children between the ages of 12 and 19 months may participate in logical thought. whether they look at something long enough during the "outcome phase," they will detect whether it is consistent with rational thought. When the result doesn't match the expected conclusion, infants show signs of surprise. This shows that they have created an expectation based on the reasons they have been given.

The study addresses the question of how babies' responses may be influenced by surface factors in the final sequence (for example, the same object appearing twice). However, further experiments showed that the babies' responses were guided by the logical nature of the scene, rather than superficial aspects of the final sequence. This reinforces the idea that babies are indeed processing logical relationships between the information presented.

The ability to engage in disjunction syllogism suggests an early developmental stage of logical thinking. This was particularly noteworthy as the infants were tested at an age before extensive language knowledge was acquired. It implies that certain aspects of logical reasoning might be inherently ingrained in the cognitive development of human infants.

The findings suggest that 12-month-old infants exhibit innate logical reasoning abilities in separation syllogism. This finding helps to understand the origins of logical thinking, suggesting that some basic forms of logical reasoning may appear at an early stage of cognitive development, even before important language acquisition occurs. The study highlights an interesting interplay between innate cognitive abilities and the development of more complex thought processes. These conclusions are symmetric with the rationalist views.

4. Limitations and further research development

Recent research by Professors Justin Halberda and Nicolo Cesana-Arlotti provides modern insights. Their experiments with pre-linguistic infants offer compelling evidence of rudimentary logical inference, suggesting an early emergence of logical thinking. While this resonates with rationalist claims, it's important to acknowledge experimental limitations and the intricacy of logic and language development.

Indeed, the question of the origin of logic has always been the guiding light of intelligence. The fusion of historical philosophical ideas with modern empirical findings drives our understanding. Since logic governs the nature of thought and is key to cognitive development, this quest is not just an intellectual exercise; It is central to the paradigm of education and the understanding of cognition. Whether through philosophical reflection, cognitive psychology, or empirical research, the nature of logic becomes more complex and fascinating as each thread is woven into the tapestry of inquiry.

Though the experiment constructed by Professors Justin Halberda and Nicolo Cesana-Arlotti provides valuable insights into the intrinsic aspects of logical reasoning in infants, there are some limitations to consider. One obvious limitation is relating to the age group studied. The study mainly focused on infants from 12 to 19 months old. This limited age range may call into question the generality of the findings. To reinforce the conclusions reached in this study, future studies could cover a broader age range, including young newborns and older infants, to better track the trajectory of logical reasoning.

Another important limitation is the challenge of directly proving an infant's innate ability to reason logically. The study of 12-month-old infants does not definitively prove that logical reasoning is present from birth. There are ethical, physical and logistical challenges to experimenting on newborns, whose cognitive and physical development may not be symmetrical with the requirements of the experiment. To solve the problem, a possible solution is studying similar logical processes in non-human primates or other animal species that share similar traits in cognitive development with human infants. These comparative studies can reveal the potential presence of certain cognitive patterns in newborns that evolve over time into more complex logical abilities.

In addition, the lack of direct physiological measures, such as brain imaging data, limits the depth of understanding of the neural mechanisms behind logical reasoning in infants. Future research could leverage advanced technologies such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) to capture patterns of neural activity associated with logical reasoning. These techniques may help to understand whether specific brain patterns are consistent with logical reasoning in different age groups, potentially supporting the notion of an underlying innate cognitive framework.

To overcome the limitations posed by studying pre-verbal infants, researchers could also explore the potential of using other forms of communication or behavioral indicators. For instance, investigating whether certain neural patterns or biomarkers associated with logical reasoning can be identified in newborns and then tracked through their development could offer a promising avenue. This approach might help bridge the gap between the immediate postnatal period and the age at which traditional experiments become feasible.3

5. Conclusion

The insights raised by this search add layers to our understanding in the long-running debate about the origins of logic - whether it is an innate human trait, or a skill acquired through experience. As the cornerstone of rational thinking, logic has a profound impact on critical analysis, decision making and problem solving in different fields. Ancient philosophers such as Immanuel Kant and John Locke cast their shadow over this argument. Kant's distinction between analytical judgment and synthetic judgment, together with his concept of a priori logic, suggests an underlying cognitive structure that supports logical reasoning. This resonates with the rationalist's notion of an inherent, innate capacity for logic. In contrast, empiricists like Locke emphasized the empirical aspect, assuming that logical principles are shaped by sensory perception. The nature-nurture dichotomy may never be definitively resolved; Instead, it forces us deeper into the realm of human cognition. This quest is not merely to uncover the origins of logic. It's about the nature of what makes us think, about the origins of human intelligence itself. As the quest continues, we are reminded that whether logic comes from our core or develops through the trials of experience, it remains an integral aspect of our human journey.

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