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What Drives Cognitive Development-School, Genetics or Both?

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Abstract

Piaget defines four successive and universal stages in human cognitive development. Extensive studies conducted during recent years show that only a third of the population continues to attain formal development (ages 12-20). The current study explores the premise that schooling is the main factor that precipitates the transition to formal thinking. We examined illiterate adults who had never attended school and were not supposed to be capable of formal thinking. Our findings show that about one-fifth of the illiterate population can perform formal thinking. However, we also found that school contributes significantly to transferring most students to the end of the concrete stage but not beyond it.

Keywords: *Human Cognitive Development, Formal Thinking, Illiterate, Cognitive Levels.*

Introduction

The issue of heredity versus environment is highly relevant in relation to the development of the child's mental abilities. How often can we consider the child's mental abilities innate and immutable, and how often are these skills perceived as the combination of education and rich stimuli provided by parents to their child?

Genetics provides the biological basis of human behavior. The discipline that deals with that is behavioral genetics. Impulses such as hunger, thirst and sex, the need for a relationship, as well as some human capabilities and talents, are innate and exist in people as part of their genetic load (Kovas et al., 2004; Krapohl et al., 2014).

Extensive studies in England show that genetic factors strongly influence mathematical functioning at age 7. In a study of 3,000 same-sex twins aged 7, which aims to examine the influence of genetic variables on performance in mathematics, reading and general intelligence (g), it was found that there was a genetic overlap between mathematics, reading and intelligence. These findings indicate that most of the genes that contribute to individual differences in mathematics are the same that affect reading and intelligence. These findings do not correspond with the results of the genetic studies, which indicate that one-third of the genetic variance in math is unrelated to reading and general intelligence (g); there are specific genes for mathematical performance (Kovas et al., 2004). Some human traits are determined by the polymorphic mechanism, i.e., a single gene determines two or more phenotypes; for instance, human blood type is determined by a single gene with three alleles ABO. However, most personal behavior traits are very complex and controlled by many genes. These features, such as weight, height, skin color, IQ, etc., are polygenic (Chen, 2013).

Searching for specific genes that influence IQ is part of the Human Genome Project. While defects in single genes, such as the Fragile X gene, can cause mental retardation, the heritability of the general cognitive ability (g) is probably influenced by a group of genes that control this characteristic (cognition); information about the location of those genes on the chromosomes and which chromosomes are they laid on, is still missing. This group of genes is called Quantitative Trait loci (QTLs). Future identification of QTLs will allow a deeper understanding of IQ, development, and interaction between the gene and the environment (Fisher, 2006).

The theoretical framework of the current paper is based on the work of Piaget and Inhelder, who focused on cognitive development (Inhelder & Piaget, 1969; Piaget, 1972). Piaget spotted four main stages in cognitive development: sensorimotor, preoperational, concrete operational stage and formal operational stage. In recent years, studies have been added relating to the cognitive development stage that continues beyond the formal stage towards the post-formal stage and reaches its equilibrium with the completion of puberty (Commons & Richards, 2003; Commons & Ross, 2008).

According to Piaget, the development course is universal, linear and continuous. In other words, children move from the sensorimotor thinking stage towards the preoperational stage to the concrete operational stage. Then, at the end of the development process, children move to the formal operational stage that can begin at age 12. This process has two components, a biological one and an environmental one; Nature and Nurture. While Piaget focused on the cognitive development of the individual, a number of extensive studies conducted around the world that examined the distribution of the cognitive level among high and junior-high students show that cognitive development has a universal pattern just until the end of the concrete stage (Green, 1983; Habib, 2007; Shayer & Adey, 1981). In other words, the entire population undergoes development regularly until the end of the concrete thinking stage at about 12. Then, a significant part of the population stops cognitive development at the concrete thinking stage, and only about 30% of the population continues cognitive development and moves to formal reasoning.

Many studies attempted to teach people' thinking'. A series of intervention programs for the development of thinking and cognitive acceleration have been developed. Yet, the idea that people can significantly improve their thinking capacities in the long term, remains controversial.

Illiteracy and Ignorance

Ignorance is a lack of knowledge. Illiteracy is the inability to read and write. There is a state of functional illiteracy, where a person acquires initial reading and writing skills, but they could be more effective in daily life behavior. According to UNESCO - 2013, there are nearly 906 million illiterate people worldwide. The number of illiterate people in Israel in 2011 reached 122,449 (33,827 men and 88,622 women) (UNESCO, 2013). Approximately 5% of population in the States is illiterate, as defined by the US government. According to the British government, 7 million citizens are illiterate. In Arab countries, more than 25% of males and 50% of women were illiterate in 2000. Most of the learning in these populations is informal and a-symbolic.

The oral calculation is very common among illiterate people ensuring proper functioning. However, writing calculation is formal, usually requires an algorithm, and refers to the absolute numerical values unrelated to context (Carraher et al., 1985; Smagorinsky & Coppock, 1995). Nunes (2010) has found that students tested orally on the subject of 'gain and loss' received higher scores than those tested in written tests (Peterson et al., 2010).

The Universal Problem

A major question regarding universal education is what drives cognitive development- Schooling or genetics? All over the world, educational policies and practices are based on the assumption that schooling

is the key to cognitive development. If this is true, illiterate adults who never attend school will lag in their cognitive development and not attain formal thinking. A recent study compared cognitive development in literate and illiterate people.

Method

For collecting data, we used a quantitative-correlative layout to examine the cognitive level according to the theory of stages. The sample included 103 illiterate subjects (n = 103), ages 40-90. The study population is heterogeneous in terms of socioeconomic status, place of residence, and work. The questions were read and explained by the researcher by demonstrating the questions. The subjects answered the questions orally, and the answers were recorded by the researcher. In addition, a control group included 1000 literate people (n = 1000). We used a test developed by the "Concepts in Math and Science in High School" team at Chelsea College, University of London, which follows Piaget and Inhelder's research (Piaget & Inhelder, 1974).

The research tool is made of a test that deals with the preservation of mass, volume, weight and density. It has 14 questions and 9 tasks. The questions examine differences and relationships between mass, weight, volume and density concepts. The test is suitable for identifying levels of cognitive thinking, from early concrete thinking (A2) to formal thinking (3A). The questions were read and explained to the subjects by demonstrating the questions. The subjects answered orally, and the answers were recorded by the researcher.

Data processing was conducted in two stages: reviewing the questionnaires; each questionnaire was tested separately, and the results were gathered and processed accordingly. Data processing was done with the tools that Shayer and Adey used in their expanded study in England. Each question in the tests examines the control of a defined cognitive level (Shayer & Adey, 1981). A score was set for each test question.

Findings and Discussion

The first research question examines whether people who did not attend school and are illiterate develop the formal thinking stage. For this purpose, the distribution of the cognitive levels of the illiterate adult population was examined. Table 1 shows the population distribution data according to the development of the cognitive stages.

Table 1: Distribution of thinking levels within illiterate participants (N = 103)

Cognitive stage	The cognitive level	Percent of the total sample
Preoperational	1B	**0%**
Early concrete	2A	**%20**
Mid concrete	2A- 2B	**%18**
Mature concrete	2B	**%27**
Concrete generalization	2B*	**%18**
Early formal	3A	**%9**
Mid formal	3A – 3B	**%6**
Mature formal	3B	**%2**
	Total	**%100**

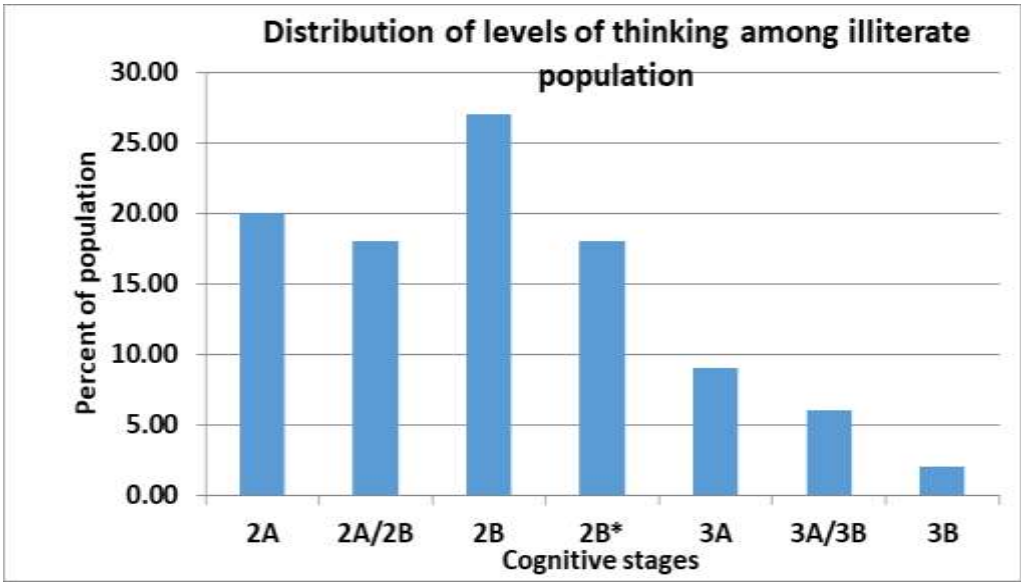

Fig. 1: Distribution of levels of thinking among the illiterate population

Fig. 1 illustrates the same distribution in a bar graph. The distribution of the cognitive levels of the illiterate participants in the test shows that everyone reaches the stage of concrete thinking, 18% reach the stage of transition from concrete thinking into formal, but 17% undergo the formal thinking stage. The findings that a significant part of the population reaches the formal thinking stage (3A, 3A/3B, 3B), despite the fact that they never went to school, suggest that an innate regulation mainly drives cognitive development.

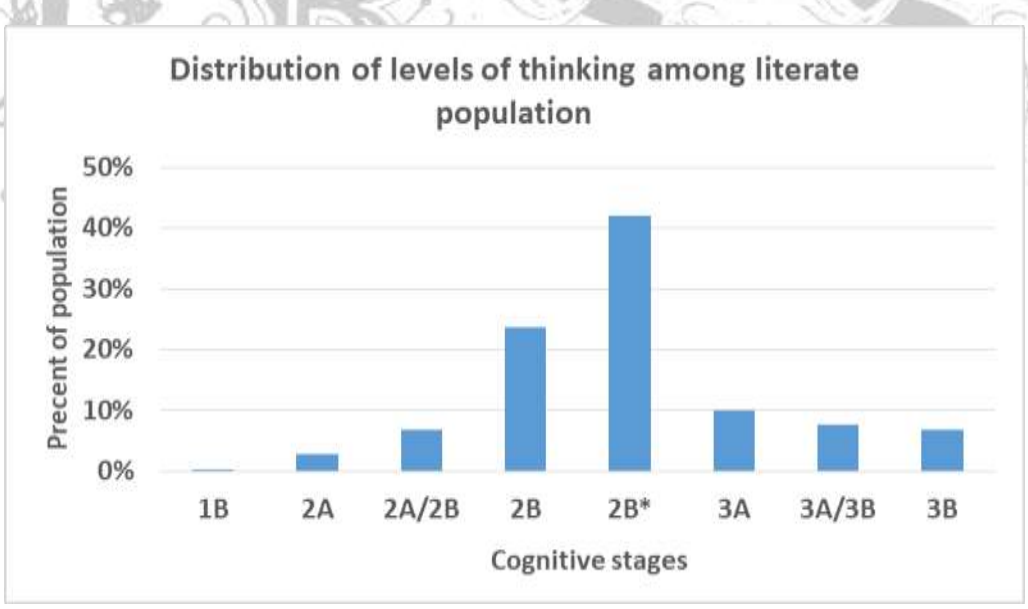

Fig. 2: Distribution of levels of thinking among the literate population

The distribution of the literate population's frequency according to the cognitive level is presented in Fig. 2. The study findings indicate that all of the population reaches the concrete stage of development. Less than 25 % continue to develop at the formal and post formal stage.

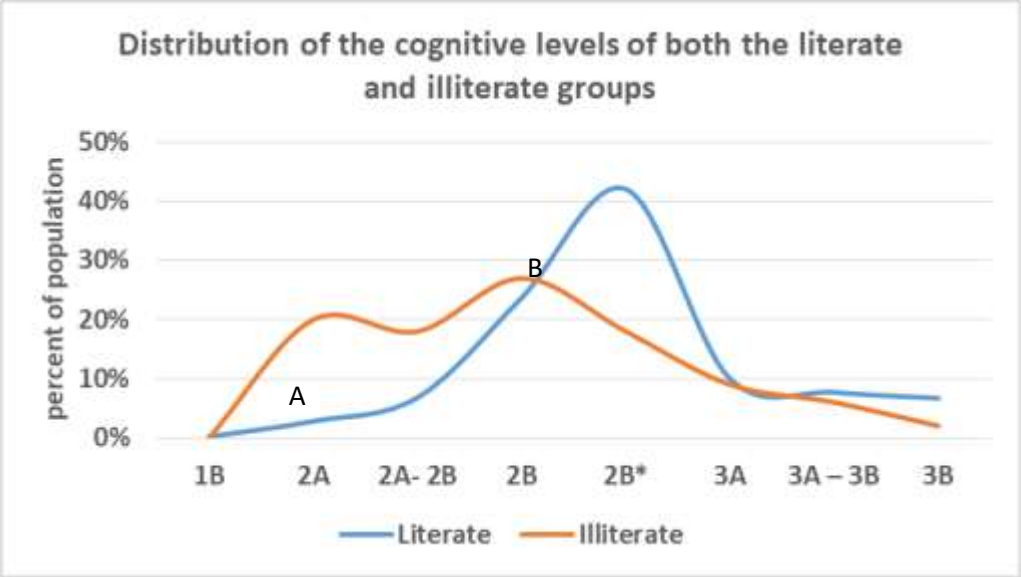

Fig. 3: Comparison between the distribution of cognitive levels of literate and illiterate groups

Fig. 3 compares the distribution of the cognitive levels of the literate and illiterate groups. When comparing the distribution of cognitive levels between the two study groups, the experimental group (N = 103 illiterate) and control group (N = 1000 literate), it was found that the percentage of the subjects who developed formal thinking was 17% for the illiterate population and 24% for the literate. In other words, the percentage of the illiterate subjects who moved to the formal thinking stage is close to that of the literate, especially at levels 3A and 3A-3B; the small difference left was at level 3B. It can be argued that the people who continued to formal thinking at school contained the genetic component, the hereditary basis for formal cognitive tools that enabled them to move to formal reasoning. School and formal education helped these capabilities to develop phenotypically. These findings do not support the approach of the socio-cultural research, which claims that all humans are born with the same cognitive capacities and social environment, and the internalization of cultural tools brings to the development of high mental functions (Luria, 1979; Ong, 1982; Vygotsky & Cole, 1978).

Another important difference is that 18% of the illiterate participants are in a transition stage, while most of them are still in the early sub-stages of concrete thinking, as opposed to a high percentage (42%) of the literate participants in the transition stage from the concrete to the formal. This finding can be explained by the effect of the school on the development of cognitive abilities. The school seems to significantly contribute to transferring most of the students to the end of the concrete and transition phases. There are sub-stages and different performance levels within the concrete stage. It seems that the school catalyzes the students' full potential and capabilities to help them reach their highest level of thinking. In other words, the school contributes to promoting thinking within the concrete stage framework; however, its effect is unable to push development beyond biological constraints.

Acquiring formal operations by a significant portion of the illiterate participants indicates the strong influence of the genetic factor on cognitive development. The current study's findings are consistent with results from twin studies that examined the correlation between the levels of intelligence and genetic relationship (Kovas et al., 2004). A study examining the genetic influence on academic achievement at the age of 16 found that 58% of the variance, in general, was influenced by heredity. This data proves that interpersonal differences in educational achievements do not result from the quality of teaching or the teachers. Most of the variance can be attributed to genetics (Shakeshaft et al., 2013). We can attribute the development of formal operations among illiterate people to hereditary factors; their lack of literacy and integration in formal education did not prevent them from developing and moving to formal reasoning.

Studies conducted over the last 20 years suggest the newborn is equipped with abilities from birth. We are talking about a bio-physiological starting point that allows a certain development direction. It seems that the person is genetically equipped with specific tools for processing information and for learning (Carey & Spelke, 1996). It likely can explain the distribution of the cognitive levels among the illiterate that some of the population has the initial capabilities (tools) to develop formal operations. In contrast, these capabilities do not exist genetically for a large portion of the population. Our findings suggest a reconsideration of the educational policies regarding cognitive acceleration at schools.

Conclusion

Based on our research, we suggest distinguishing between cognitive development and cognitive growth. Cognitive development is universally regulated intrinsically by the genome (Innately) and thus cannot be "accelerated". However, cognitive growth is the product of learning and continues over time. It is the kind of knowledge acquired that is constrained by the developmental stage and the specific modules that were differentiated. If our findings are correct, it requires a whole reform in education strategies.

Declarations

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