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On the Capacity to Change: Exploring the Malleability of Intelligence

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"Does intelligence have the capacity to change?" Addressing this question is of prime importance, as how we characterize intelligence can have significant consequences for individuals. The following paper will explore the controversy related to the malleability of intelligence. It will critically analyze the nature and nurture aspects of the debate, and suggest further research be conducted on the relationship between malleability and the growth mindset.

Keywords: Intelligence, malleability, growth mindset

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Intelligence is a broad spectrum of differing abilities, as depicted by the Cattell-Horn-Carroll model of cognitive abilities (Flanagan & Harrison, 2012). It has been one of the most widely researched constructs, yet it is still heavily debated today (Plomin & Spinath, 2004). In particular, there have been many objections related to the different factors that contribute to intelligence. On the one hand, many theorists strongly believe that genes play a predominant role in intellectual capacity, and that heredity is the principle, if not only, determinant of intelligence (Plomin & Spinath, 2004). On the other hand, many researchers believe that environmental factors contribute substantially to cognitive ability and can even alter genetic predisposition (Nesbitt et al., 2012; Day & Sweatt, 2011). The nature-nurture debate of intelligence has spurred controversy for decades, particularly with regards to one specific aspect: its capacity to change. The malleability of intelligence continues to spark fervent discussion, especially with the completion of the Human Genome Project, which is an international research project attempting to completely sequence human DNA, and the rise in research in epigenetics, which refers to changes in gene expression based on environmental factors (Bjorklund, 2006; Day & Sweatt, 2011). Much time and research has been spent in attempting to answer the important question, "Does intelligence have the capacity to change?" As we will see, further research should be conducted on the relationship between malleability and the growth mindset.

Addressing this question is of prime importance, as how we characterize intelligence can have significant consequences for individuals. For instance, we utilize tests of cognitive abilities to estimate an individual's intellectual capacities in the education system to help address students' academic difficulties (Kranzler & Floyd, 2013). The conclusions we draw from these tests have a significant impact on the solutions offered to students, as well as the students' perspectives of their difficulties. If the administrator's conclusions are based on a false interpretation of intelligence, the

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solutions offered may have detrimental effects for the students. For example, students may believe that they are incapable of attaining specific grades because they are simply not as smart as other individuals. They may be repeatedly pushed to learn material in a specific way, when they are unable to grasp the material the same way as other students. Students who have a more malleable view of intelligence tend to put more effort in tasks and seek challenges more often than students who have a more fixed view of intelligence (Yeager & Dweck, 2012). The following paper will explore the controversy related to the malleability of intelligence. It will critically analyze the nature and nurture aspects of the debate and attempt to offer a solution as to whether intelligence has the capacity to change.

Historical Perspective of Intelligence Malleability

While the malleability of intelligence has long been debated, increasing controversy stemmed from the publication of *The Bell Curve* in 1994. Within the book, the authors asserted that intelligence is an important predictor of many life outcomes, such as social class, social economic status and employment outcome (Herrnstein & Murray, 1994). Their book suggested that a high value for heritability, which is a correlation ranked between 0 and 1, limits the extent to which intelligence can be increased by a change in environment (Wahlsten, 1997). In fact, they asserted that intelligence remains stable and is unlikely to change. The arrival of *The Bell Curve* in 1994 caused controversy within the population (Zenderland, 1997), as individuals did not want to believe that their own intellectual potential was predicted by their genetic predisposition and, more importantly, that there was nothing that could be done to change it.

Despite the public's disapproval, *The Bell Curve* nevertheless expressed an important aspect of intelligence: its heritability. Many researchers agreed on this component and provided evidence for the construct. Gottfredson (1997) conducted a survey that asked professionals in the field how they characterized intelligence. A main point of agreement was that intelligence was highly heritable and that, indeed, it changed little over time. More recently, Rushton and Jenson (2005), strong advocates for the heritability of intelligence, have performed multiple studies, suggesting that differences in intelligence might be related to genetic differences. For instance, they have conducted studies to investigate the causes behind group differences in mean IQ. Their evidence suggested that these differences were mainly due to genetic components (Rushton & Jenson, 2005). The more heritable a trait, the more often it is passed down from generation to generation, and the less likely it is to change. However, it is important to note that this research, though previously accepted, is highly controversial today, especially when considering how intelligence tests are catered to a specific subset of a population and unfairly portray other groups.

Although many researchers supported the heritability and stability of intelligence, other theorists postulated a different view. In particular, Gardner (2006) believed that intelligence was strongly affected by individuals' environments, as well as the culture surrounding them. His Multiple Intelligence theory argues that there are eight different types of intelligence, and an individuals' strengths and weaknesses in terms of these abilities are strongly related to their environment (Gardner, 2006). In fact, if individuals were to change their environment, they would be able to develop and strengthen their other intelligences as well. Gardner's theory, although difficult to prove, has spurred interest in the impact of the environment on intelligence. In more recent years, Richard Nisbett (2009), a prominent figure advocating for the malleability of intelligence, asserted that individual differences in intelligence are principally resulting from societal and cultural differences. Nisbett suggested that by bettering a student's school environment, for example, through proper interventions and a positive and academically-geared frame of mind, the student's intelligence will increase. In fact, research has found that through proper working memory interventions, individuals also improved their fluid intelligence, that is, their abilities to solve novel problems through inductive and deductive reasoning (Nisbett et al., 2012). As our environment changes, more opportunities arise to stimulate our intellectual capacities, and our intelligence changes as well.

There have been many theories both to support the heritability and stability of intelligence. There have also been many studies to support environmental factors and the capacity of intelligence to change over time. The controversy surrounds the evidence that supports each claim.

Evidence Against the Malleability of Intelligence

The heritability of intelligence provides evidence supporting the stability of intelligence. Brody (1994) found that genes influence the way in which a trait is expressed. Traits found to be highly developmentally stable may also be significantly heritable, in part due to strong directional selection (Moller & Thornhill, 1997). Additionally, a recent study examining the genetic and environmental contributions of intelligence found that phenotypic stability primarily resulted from additive genetic factors and the stability of common environment (Franic et al., 2014). This research provides evidence that the more heritable a trait is, the less likely it is to change over time. Animal, family and twin, developmental and adoption studies have all contributed to providing evidence to support the role of genes on intelligence, as well as the stability of this trait over time.

Animal Studies

Animal studies have been performed and, through genetic manipulations, have provided evidence for the role of heritability in intelligence. A classic experiment was conducted by Tolman in 1924 and repeated by Tryon in later years (1940), in which rats were bred in a specific manner to assess the heritability of intelligence. Rats were inbred based on their strong or weak performance on a maze, leading to maze-bright and maze-dull rats. Through generations of breeding, the researchers were able to significantly separate bright rats from dull rats in relation to performance on the particular maze, thereby providing evidence for the relationship between the specific traits and genes. These studies showed the importance of genetic input on traits related to cognitive ability, in this case on the performance of rats to quickly complete a maze. Further studies were also conducted on inbred strains of mice to investigate the contribution of genetics to individual differences for certain aspects of learning and intelligence (Plomin & Spinath, 2004). For instance, Zoubovsky et al. (2011) conducted a study in which the neural nitric oxide synthase gene (nNOS), which forms nitric oxide, was genetically deleted in mice. These mice then underwent behavioural tests, including open field test, novel object recognition test, fear conditioning test, Y-maze test, and delayed non-matching to place T-maze test (Zoubovsky et al., 2011). Researchers reported that nNOS knockout (KO) mice exhibited behavioural deficits, and, importantly, they displayed impairments in specific cognitive abilities, such as working memory and mild deficits in object recognition memory (Zoubovsky et al., 2011). These animal studies have shown that both the presence and removal of genes have a significant impact on cognitive abilities, and they provide evidence for the heritability of traits related to intelligence.

Family and Twin Studies

Family and twin studies have been conducted to investigate the role of heredity in intelligence and have shown a greater stability in cognitive abilities. A study of more than 10,000 monozygotic and dizygotic twins showed that the heritability of intelligence in monozygotic twins is approximately 0.86 in correlation and the heritability of intelligence in dizygotic twins is approximately 0.60 in correlation (Plomin, DeFries, McClearn, & McGuffin, 2001). These studies demonstrate that the more genes individuals have in common with one another, such as with monozygotic twins, the greater the similarities in their levels of intelligence. Further studies have also shown that variation in total gray matter, which is related to cognitive functioning, and total white matter, which is related to processing speed, in adult human brains is 70-80% genetically determined (Baaré, 2001; Pennington et al., 2000; Pfefferbaum et al., 2000). Cross-trait and cross-twin correlations were also assessed, and evidence showed a strong genetic component in the neuronal network for human intelligence, that is, the circuit of neurons that fire when cognitive processes are engaged (Hulshoff et al., 2006). Finally, a within-family association study was performed to investigate the presence of the *CHRM2* gene, which is thought to be related to, among other things, neuronal excitability, synaptic plasticity, and cognitive processes such as learning and memory (Gosso et al., 2006). Results showed a significant association between the *CHRM2* gene and intelligence and a strong presence of the gene within families. In sum, these family and twin studies have shown a significant genetic impact on intelligence, thereby providing evidence for its heredity. Furthermore, intelligence was unlikely to change throughout the lifespan, despite the unshared environment between family members. Indeed, the more heritable a trait, the less likely it will be affected by surrounding environment and the more stable it will be over time.

Developmental Studies

The heritability of intelligence has been shown to increase until adulthood. Indeed, studies show that the difference between monozygotic and dizygotic twin correlations increases slightly from early to middle childhood and then dramatically into adulthood (McGue, Bouchard, Iacono, & Lykken, 1993), resulting in a greater heritability for intelligence. Because there have been relatively few twin studies regarding intelligence that have included adults, summaries of intelligence data mainly provide evidence for the heritability of intelligence in childhood (Plomin & Spinath, 2004). However, results from a 20-year longitudinal adoption study support the view of increasing heritability (Plomin, Fulker, Corley, & DeFries, 1997), as results indicate that adopted children more closely resembled their biological parents' intelligence scores as they became older. In sum, although intelligence has a high degree of heritability in childhood, studies have found that this trait increases in heritability in adulthood, making it less subject to change.

Adoption Studies

Finally, adoption studies were examined to determine the role of genetics and environment on intelligence. According to these studies, biological parents and their children who were given up for adoption, siblings that were adopted apart, and monozygotic twins adopted apart all presented substantial genetic influence (Plomin & Spinath, 2004). In fact, there are adoption studies of contrasted environments (Locurto, 1990), wherein the biological family's socioeconomic status is considerably different from the adopted family's socioeconomic status and provides better chances for environmental effects. These studies provided malleability estimates that were modest, suggesting a more stable view of intelligence. The high levels of heredity in intelligence scores suggest little effect of environmental factors and provide strong evidence to support the stability of intelligence.

In sum, heritability is an important factor related to intelligence and there is strong evidence for its stability over time (Moller & Thornhill, 1994). Support for the heritability of intelligence and the role of genes in cognitive abilities was shown through animal studies, family and twin studies, developmental studies and, finally, through adoption studies. Further studies supported the argument that trait heritability is a contributing factor to trait stability (Moller & Thornhill, 1994).

Evidence to Support the Malleability of Intelligence

In opposition to this research, environmental factors have also been studied and provide evidence to support the capacity of intelligence to change over time. Specific scientific fields have provided evidence on the malleability of intelligence. In particular, neuroplasticity, epigenetics, and the presence of a growth mindset all support the malleable property of intelligence.

Neuroplasticity Studies

Studies have shown that through our environment, our brains have the ability to adapt our neural pathways and strengthen them through myelination, thereby affecting our cognitive capacity (Lee, Yan, & Lu, 2012; Takeuchi et al., 2012; Landon-Murray & Anderson, 2013). Myelination is the process through which an insulation layer surrounds the axon of the neuron to accelerate communication between different parts of the brain and body. The strengthening of neural pathways, known as neuroplasticity, has been studied extensively in the last few decades and studies and case studies have supported this concept. For instance, Lee, Yan and Lu (2012) published a case study on a boy who survived a major stroke at 40 days old. Despite his intracerebral hemorrhagic stroke, which resulted in his hospitalization for tremors and weaknesses, the young boy almost completely recovered his motor abilities. Furthermore, his intelligence appeared unaffected, with the predominant hypothesis being the neuroplastic potential of the human brain (Lee et al., 2012). Another study investigated the way in which the internet and other related technologies change the way individuals engage information and the changes these technologies make to cognitive functioning (Landon-Murray & Anderson, 2013). Results showed that these technologies have affected organization in the brain and have allowed individuals more focused and disciplined thinking, which is a key component in many cognitive abilities. Neuronal circuits in the brain have the capacity to adapt and strengthen, thus increasing cognitive ability and therefore intelligence. Takeuchi et al. (2012) investigated whether cognitive abilities in the elderly could be improved upon with certain activities. They found that processing speed training, in which participants are instructed and able to practice speeded tasks, improves performance on novel untrained processing speed tasks. Training is also associated with changes in the gray matter structures of the brain, neural changes associated with speeded cognitive processes, and functional activity related to simple cognitive processes. In other words, processing speed training has led to neuroplastic changes in the brain, thereby affecting cognitive processes. These studies provide evidence to support the ability of intelligence to increase throughout the lifespan through neuroplasticity.

Epigenetics Studies

Although there have been multiple studies advocating for the effect of genes on intelligence, growing research in epigenetics, that is, the change in genetic expression due to environmental factors, suggest that our environment may play a role in the expression of certain genes over others, thus advocating for the impact of environmental factors on the genetic expression of intelligence. A change in environment may lead to a change in genetic expression, which would result in a change in intelligence over time. In particular, one study suggested that long-term behavioural change may be associated with epigenetic regulation of transcription in the central nervous system (Day & Sweatt, 2011). Environmental factors have been found to either increase or decrease DNA methylation in genes (the addition of methyl groups to DNA to monitor the gene's activity), thus affecting their level of expression. In fact, evidence suggests that changes in DNA methylation contribute to memory formation and maintenance, a predominant component of certain cognitive abilities (Day & Sweatt, 2011). In other words, through cognitive epigenetics, DNA methylation for genes related to memory may be increased or decreased, thus affecting the expression of the gene and the individual's performance on memory tasks. This study on DNA methylation has provided evidence for epigenetic components relative to cognitive abilities; a change in environment could lead to a change in gene expression and a decrease in the heritability and stability of intelligence.

Growth Mindsets

A possible explanation for the stability of intelligence is the fixed mindset, in which individuals believe that their abilities are given at birth and no amount of effort will lead to improved outcomes in performance. In contrast to the fixed mindset, simply believing that intelligence has the capacity to change may result in an increase in an individual's cognitive abilities and increase his or her performance in academic disciplines as well (Blackwell, Trezesniewski, & Dweck, 2007). A longitudinal study in adolescents explored the impact of the growth mindset, in which people believe that the more effort you put into a task, the better the results will be (Blackwell et al., 2007). Results showed that when individuals were encouraged to believe that intelligence was changeable rather than fixed, they performed higher academically and their scores on tests increased. However, when individuals believed that intelligence was a fixed, unchangeable concept, their performances remained stable. This study also explored the relationship between mindset and income. The research suggests that students from lower-income families may be less likely to hold a growth mindset compared to higher-income peers. However, when they do hold a growth mindset, they are less prone to the effects of poverty on achievement (Blackwell et al., 2007). Academic achievement is not an explicit measurement of intelligence. However, research has shown that performance on IQ tests is a reasonable predictor of grades at school, performance at work, and aspects of success in life, including income (Gottfredson, 2004). These results suggest that having a growth mindset may alter an individual's performance on measures or outcomes related to intelligence. However, further research is recommended to explore the direct relationship between intelligence and the growth mindset.

In sum, evidence from neuroplasticity, epigenetics, and the growth mindset suggests that environmental factors may play a role in intelligence. In fact, when an individuals' environment has changed, their academic and intellectual output have been shown to change as well.

Discussion

The controversy related to the malleability of intelligence is ongoing. There has been much evidence both to support the stability of intelligence and to advocate for its capacity to change. On the one hand, some studies support the idea that intelligence is highly heritable, and therefore less conducive to change. On the other hand, studies have found that certain environmental factors may also play a role in intelligence, thus supporting the malleability of intelligence. The studies that were analyzed provide support for both sides of the argument. However, an important theory that should be highlighted is that simply believing in the malleability of intelligence may result in better performance on intelligence tasks. Indeed, a study showed that the belief in intelligence malleability may actually increase an individual's performance on test of cognitive abilities (Blackwell et al., 2007). Furthermore, the belief that intelligence is unchangeable may be the reason why intelligence has remained stable in populations (Aronson, Fried, & Good, 2002). Another theory is that by believing that cognitive abilities can be improved, individuals have an increased motivation to apply effort to tasks that are cognitively challenging. Conversely, by believing that intelligence is heritable and unchangeable, individuals might have a "why bother" approach to intellectual obstacles, thus preventing them from increasing their effort to overcome these impediments. Therefore, it is plausible that the malleability of intelligence is predicated by individual belief on whether intelligence can change. Further research should be conducted in this area to determine whether growth mindset impacts the malleability of intelligence.

Conclusion

The nature-nurture debate of intelligence has spurred much controversy, particularly in regard to the capacity of intelligence to change. Indeed, much research has been conducted to determine the malleability of intelligence. On the one hand, animal, family, twin, developmental and adoption studies have found that intelligence is highly heritable and therefore highly stable. On the other hand, studies in neuroplasticity, epigenetics and different mindsets support the role of environmental factors in the malleability of intelligence. However, one particular theory behind the abundance of evidence supporting both the stability and malleability of intelligence pertains to the growth mindset and the belief that intelligence can change. Indeed, primary research suggests that simply believing in the malleability of intelligence can increase an individual's motivation and effort, and subsequently improve cognitive performance on ability tests, though further research is warranted in this area. It is therefore suggested that more research be conducted on the relationship between the malleability of intelligence and the growth mindset.

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