Review

The relationship between brain size and cognitive ability

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ABSTRACT

This review examines the relationship between brain size and human intelligence by integrating findings from neuroimaging studies, genetic analyses and large-scale population research. Early theories, such as Spearman's concept of general intelligence (*g*), laid the foundation for understanding cognitive ability as a unified construct. Evidence from modern studies suggests that while brain size has a measurable and partly causal association with intelligence, its effect is modest. Research highlights that grey matter volume, specific brain regions and neural activity contribute more significantly than overall brain size alone. Additionally, the efficiency and connectivity of large-scale brain networks, particularly the frontoparietal system, play a central role in cognitive functioning. Overall, intelligence emerges from a complex interaction between brain structure, neural organization and functional connectivity rather than simply the size of the brain.

Keywords: Human intelligence; Brain size; Grey matter; White matter; Neuroimaging; Cognitive ability; Brain networks; Frontoparietal network; MRI; GWAS

INTRODUCTION

Spearman (1904), one of the early pioneers in intelligence research, argued that intelligence could be measured scientifically. By studying children's school grades, the author noticed that students who performed well in one subject usually did well in others too. The author called this pattern the positive manifold. Based on this observation, Spearman introduced the idea of *g* (general intelligence), suggesting that a single underlying ability influences performance across different cognitive tasks. Human intelligence is the mental ability to learn from experience, adjust to new situations, understand abstract ideas and use knowledge to deal effectively with the environment (Sternberg 2025). Reasoning, problem solving and learning are crucial facets of human intelligence (Colom et al 2010).

Brain volume and intelligence: insights from neuroimaging and structural brain research

A positive relationship between brain volume and intelligence has been suspected since the 19th century and empirical studies seem to support this hypothesis (Nave et al 2019). Neuroimaging is very important for studying how the brain works because it lets us observe its structure and activity without surgery (Litwinczuk et al 2023, Morita et al 2016). By looking at images of the brain, researchers can see how different areas are involved in processes like perception, attention, memory, language, decision-making and emotion (Elam et al 2021).

People with larger brains are often considered more intelligent. Brain size is also one of the few measures scientists can study in fossils, using skull impressions called endocasts (Jerison 1973). Because of this, brain size has become an important clue for researchers trying to understand how human intelligence has evolved over time (Burkart et al 2017). An extensive literature review supported the parieto-frontal integration theory, which claims that the parietal cortex and the frontal cortex are the core regions involved in intelligence (Jung and Haier 2007). Higher intelligence is linked to small but consistent differences in brain structure, both in grey matter (like cortical thickness and key regions such as the thalamus and insula) and white matter integrity (better neural connectivity), though these effects are generally modest and change with age (Deary et al 2022).

This review brings together findings from brain imaging studies, large datasets and previous research to understand how brain size relates to intelligence. It highlights that while brain size matters, intelligence is better explained by a combination of brain volume, the type of brain tissue and how efficiently different brain regions work together.

Empirical evidence on the relationship between brain size and intelligence

The study by Lee et al (2019) provides strong evidence that brain size has a genuine, though modest, causal influence on human intelligence. Using within-family comparisons, the researchers found that individuals with larger brains tended to have higher intelligence scores even when compared to their own siblings. This means the relationship cannot be fully explained by shared family environment or factors like assortative mating. In addition, genetic analyses (GWAS) showed significant correlations between genes linked to larger brain size and those associated with intelligence and educational attainment.

Advanced modeling further indicated that most of this relationship reflects a causal pathway from brain size to intelligence, rather than the reverse or simply shared genetic effects. Overall, the findings suggest that while brain size does play a role in intelligence, its effect is relatively small and likely works alongside many other biological and environmental factors.

The meta-analysis by Gignac and Bates (2017) examined the relationship between brain volume and intelligence in healthy adults and found a moderate positive correlation. By focusing only on adult, non-clinical samples and using improved statistical methods, the study provided a more accurate estimate than earlier research. Importantly, it showed that the strength of this relationship depends on how well intelligence is measured; studies using higher-quality IQ tests reported stronger correlations. This suggests that earlier studies may have underestimated the true link between brain size and intelligence, and highlights that measurement quality plays a key role in understanding this relationship.

The study by Andreasen et al (1993) examined how different brain structures relate to intelligence in healthy adults using MRI and IQ testing. The results showed that higher intelligence was positively associated with larger overall brain size and key regions such as the cerebral hemispheres, temporal lobes, hippocampus and cerebellum, while no significant links were found with the caudate or ventricles.

Importantly, intelligence was related specifically to greater grey matter volume rather than white matter or cerebrospinal fluid, suggesting that neuron-rich areas play a larger role in cognitive ability. Both men and women showed these brain-IQ relationships, though patterns differed slightly by gender. Overall, the findings indicated moderate to strong correlations, meaning brain structure contributes meaningfully to intelligence, but is only one part of a more complex picture involving other biological and environmental factors.

The study by Egan et al (1994) explored how brain volume relates not only to intelligence but also to memory, processing speed and brain activity (auditory evoked potentials) in healthy adults. The findings showed a positive relationship between brain size and IQ, which became much stronger after statistical correction, suggesting that larger brains are associated with higher intelligence. Different brain tissues also played distinct roles, with grey matter more closely linked to verbal abilities and white matter to performance skills. Brain volume was moderately related to memory but showed only weak links with processing speed. Among brain activity measures, the P300 signal stood out as consistently associated with better cognitive performance, while other signals showed little or inconsistent relationships. Overall, the study highlighted that intelligence is influenced not just by brain size, but also by brain function and specific neural processes.

The review by Colom et al (2010) explains that human intelligence is not determined by brain size alone, but by how different brain regions work together as a network. Drawing on imaging, lesion, and meta-analytic studies, the authors show that higher intelligence is linked to greater grey matter in key areas (like frontal and parietal regions) and better white matter connectivity. Functional studies further reveal that people with higher IQs use these networks more efficiently during thinking tasks. Overall, the review concludes that intelligence mainly arises from the efficiency and connectivity of large-scale brain networks, especially the frontoparietal network, while brain size plays only a modest role.

The large-scale study by Nave et al (2019) found that bigger brains are associated with slightly higher intelligence, but the relationship is modest. Using a large sample from the UK Biobank, the study showed a small positive correlation between total brain volume and cognitive ability, with brain size explaining only a small portion of differences in intelligence. Grey matter contributed more to this relationship than white matter, while links with other cognitive skills like memory and reaction time were weak or inconsistent. Overall, the findings suggest that although larger brain volume is linked to higher intelligence, it plays only a limited role and many other factors are also important.

Brain size as a limited but meaningful factor in intelligence

Taken together, these studies show a clear and consistent pattern: brain size does matter for intelligence, but only to a limited extent and it is far from the whole story. Evidence from Lee et al (2019) and Nave et al (2019) suggests that the relationship between brain size and intelligence is real and partly causal, not just due to family background or other confounding factors. However, the effect is modest, explaining only a small proportion of differences in intelligence across individuals. The findings from Gignac and Bates (2017) indicate that the strength of this relationship depends on how well intelligence is measured, meaning that better tests reveal a somewhat stronger (but still moderate) link. This suggests earlier research may have underestimated the association. Studies like Andreasen et al (1993) and Egan et al (1994) show that not all brain tissue contributes equally. Grey matter, which contains neuron cell bodies, is more strongly related to intelligence than white matter or cerebrospinal fluid. They also highlight that specific brain regions and brain function (eg neural activity like P300) are important, not just overall size. The review by Colom et al (2010) provides a broader interpretation: intelligence mainly depends on the efficiency and connectivity of brain networks, especially the frontoparietal system. This shifts the focus from 'how big the brain is' to how well different parts of the brain communicate and work together. Thus brain size can be seen as a basic structural factor that sets some limits on intelligence, but the quality of brain organization, such as neural connectivity, efficiency and tissue composition, is far more important. Intelligence is, therefore, best understood as a product of a complex, integrated brain system rather than simply a matter of having a bigger brain.

CONCLUSION

The research shows that brain size has a real but limited role in human intelligence. Studies using genetic data and large population samples suggest that people with larger brains tend to have slightly higher intelligence and this relationship is partly causal. However, brain size explains only a small portion of individual differences in intelligence, indicating that it is not the main factor. More importantly, the structure and functioning of the brain play a much bigger role. Grey matter, which contains neuron cell bodies, is more strongly linked to intelligence than other brain tissues. Specific regions such as the frontal and parietal lobes, hippocampus and cerebellum are particularly important for reasoning, memory and problem-solving. In addition, brain activity and processes like memory and neural efficiency also contribute significantly. Modern research emphasizes that intelligence depends largely on how efficiently different parts of the brain communicate. Strong connectivity and well-organized brain networks, especially the frontoparietal network, are key to higher cognitive ability.

The brain size can be seen as a basic structural factor, but intelligence is better understood as the result of a complex interaction between brain structure, tissue composition and network efficiency. Simply put, it is not just how big the brain is, but how well it works as a connected system that determines intelligence.

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