Current Biology

Report

# Regional Variations in Brain Gyrification Are Associated with General Cognitive Ability in Humans

## Highlights

- Associations between local brain gyrification and general intelligence (*g*) were found
- Regional gyrification-*g* associations predominated in frontoparietal regions
- The results were confirmed in two large, independent samples (children and adults)
- The findings were consistent across age, sex, and method of calculating of *g*

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## In Brief

Gregory et al. describe associations between regional brain gyrification and general cognitive ability in two large, independent cohorts analyzed using parallel methodologies. The neuroanatomical pattern found is congruent with leading proposals concerning the neural basis of cognitive ability and consistent with comparative biological research.

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## SUMMARY

**Searching for a neurobiological understanding of human intellectual capabilities has long occupied those very capabilities. Brain gyrification, or folding of the cortex, is as highly evolved and variable a characteristic in humans as is intelligence. Indeed, gyrification scales with brain size, and relationships between brain size and intelligence have been demonstrated in humans [1–3]. However, gyrification shows a large degree of variability that is independent from brain size [4–6], suggesting that the former may independently contribute to cognitive abilities and thus supporting a direct investigation of this parameter in the context of intelligence. Moreover, uncovering the regional pattern of such an association could offer insights into evolutionary and neural mechanisms. We tested for this brain-behavior relationship in two separate, independently collected, large cohorts—440 healthy adults and 662 healthy children—using high-resolution structural neuroimaging and comprehensive neuropsychometric batteries. In both samples, general cognitive ability was significantly associated ($p_{FDR} < 0.01$) with increasing gyrification in a network of neocortical regions, including large portions of the prefrontal cortex, inferior parietal lobule, and temporoparietal junction, as well as the insula, cingulate cortex, and fusiform gyrus, a regional distribution that was nearly identical in both samples (Dice similarity coefficient = 0.80). This neuroanatomical pattern is consistent with an existing, well-known proposal, the Parieto-Frontal Integration Theory of intelligence [7], and is also consistent with research in comparative evolutionary biology showing rapid neocortical expansion of these regions in humans relative to other species. These data provide a framework for understanding the neurobiology of human cognitive abilities and suggest a potential neurocellular association.**

## RESULTS

The overall degree of cortical folding, or gyrification, in the brain has been associated with cognitive ability across species in a general sense, with putatively more intelligent species such as primates, cetaceans, and pachyderms exhibiting greater brain gyrification [6]. However, even among these species, the regional pattern of gyrification differs; for example, humans have evolved a unique pattern of relatively larger, more developed frontal lobes [8, 9]. This observation suggests that increased gyrification in specific brain regions may contribute to differences in cognitive ability in humans. The few studies testing for such associations in people have provided decidedly mixed results. The only prior investigation of regional associations between gyrification and cognition used a proxy measure of gyrification, cortical curvature, in a small sample and found only a restricted region of the medial temporo-occipital junction to be associated with IQ [10]. In another recent study, average gyrification across the whole brain was associated with cognitive ability in an aging sample, though the effect was mainly driven by brain size, and regional associations were not examined [11].

Various measures have been used to quantify brain gyrification over the past century [12, 13]. The current gold-standard metric, gyrification index (GI), was originally described on two-dimensional coronal slices [5] and quantifies as the ratio of pial surface area to the surface area of the cortical hull, or outer contour of the brain. GI can also be calculated in three dimensions as an average global whole-brain measure (GGI), or regionally as a local gyrification index (LGI). The analytic approach employed here calculates the LGI of each of 198,812 nodes per hemisphere of a standardized mesh representation of the pial brain surface [14], as well as GGI. The regionally specific nature of LGI allows for neuroanatomically specific delineation of associations of brain gyrification with