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Brain Morphology in Extraordinary Geometrician Harold Coxeter: implications for connectivity

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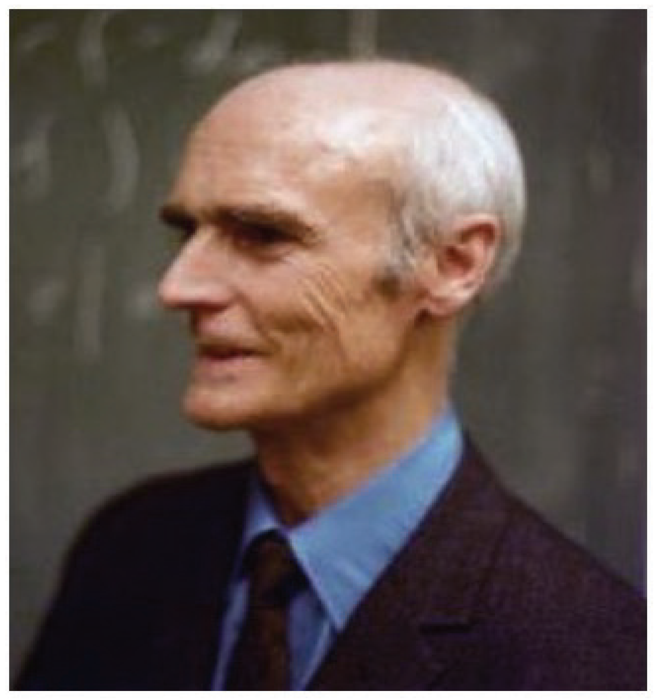
BACKGROUND

- Extensive previous research has focused on brain-behavior relationships in cognitive decline
- Comparatively little research has been done on individuals deemed to have exceptional cognitive abilities
- Harold Coxeter (HC) was an extraordinary geometrician and one of the foremost mathematical minds of the 20th century (Figure 1)
- HC volunteered to have his brain studied after learning about the neuroanatomical analysis of Albert Einstein's brain[1]
- The aim of this study was to explore whether HC's exceptional geometrical ability was related to variations in brain anatomy, with particular focus on the structure of the parietal lobes



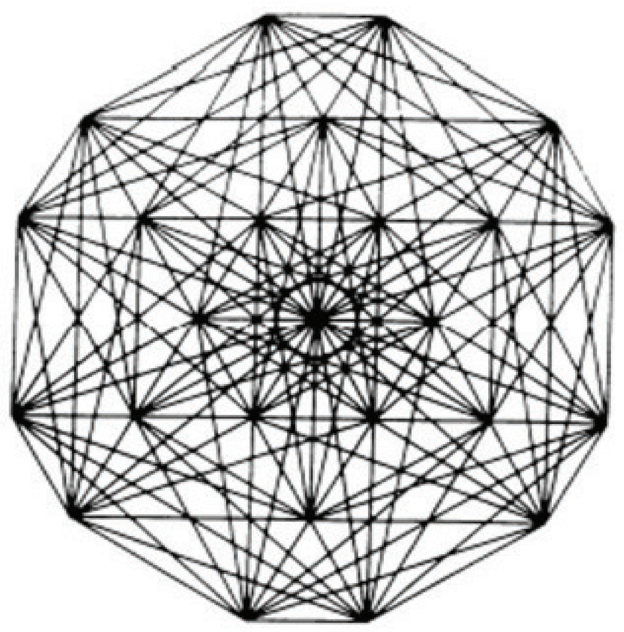


Figure 1a (left): A photo of Dr. HSM Coxeter; Wikimedia Commons. Figure 1b (right): A Hessian polyhedron 3{3}3{3}3 with projection vector (2, 1, 1), an object Coxeter features in "Portraits of a Family of Complex Polytopes" (Coxeter & Shephard, 1992).

METHODS

- At age 93, Harold Coxeter (HC) underwent a structural MRI scan
- The MRI data were analyzed using SABRE (Semi-Automated Brain Region Extraction[2] Figure 2), and FreeSurfer
- HC's brain images were compared to those of 24 neurotypical senior-aged men

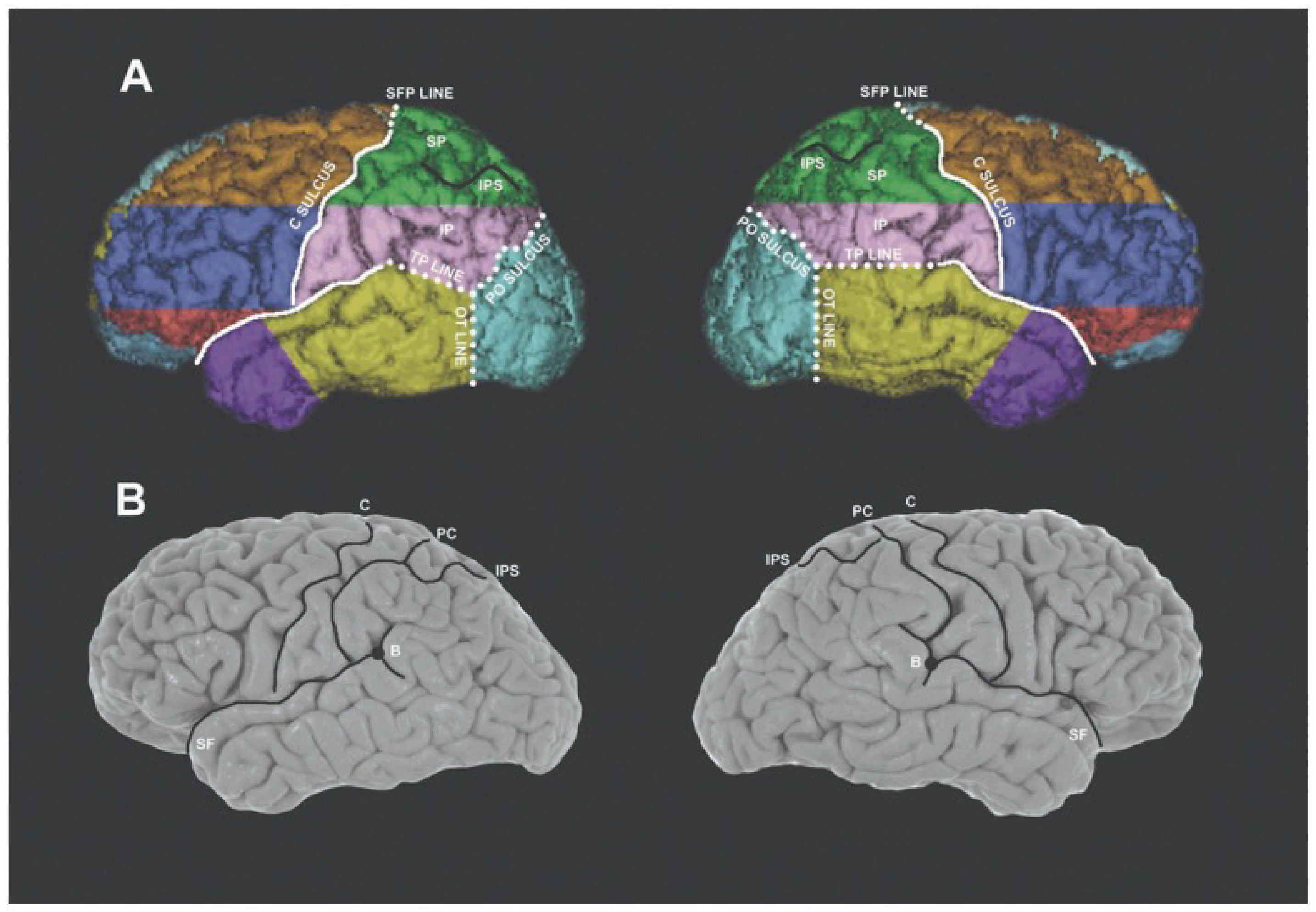


Figure 2: **A** shows the left and right hemispheres of the SABRE-generated parcellation of the MRI of HC's brain *in vivo* at age 93. **B** shows the hemispheres of HC's postmortem brain at age 96. Abbreviations:; B, point of bifurcation of the Sylvian fissure ; C, central sulcus; IPS, intraparietal sulcus; PC, postcentral sulcus; SF, Sylvian fissure.

- Grey matter (GM) and white matter (WM) volumes were assessed in both HC and the control group, focused on brain regions linked to mathematical cognition and visuospatial abilities

RESULTS

- No significant differences in GM volumes were found between HC and controls for any brain regions
- This finding was consistent across both SABRE and FreeSurfer analyses
- HC exhibited larger WM volumes in several brain regions compared to the control group (Figure 3), notably in:
  - Right and left superior parietal regions
  - Left superior frontal region
  - Left occipital region
  - Right posterior temporal region
- These regions support mathematical and visuospatial cognition[3]
- In these regions, HC's WM volume exceeded the control group mean by at least two standard deviations

RESULTS

- Additionally, HC's WM volumes were greater than those of any individual in the control group for each of the five significant regions

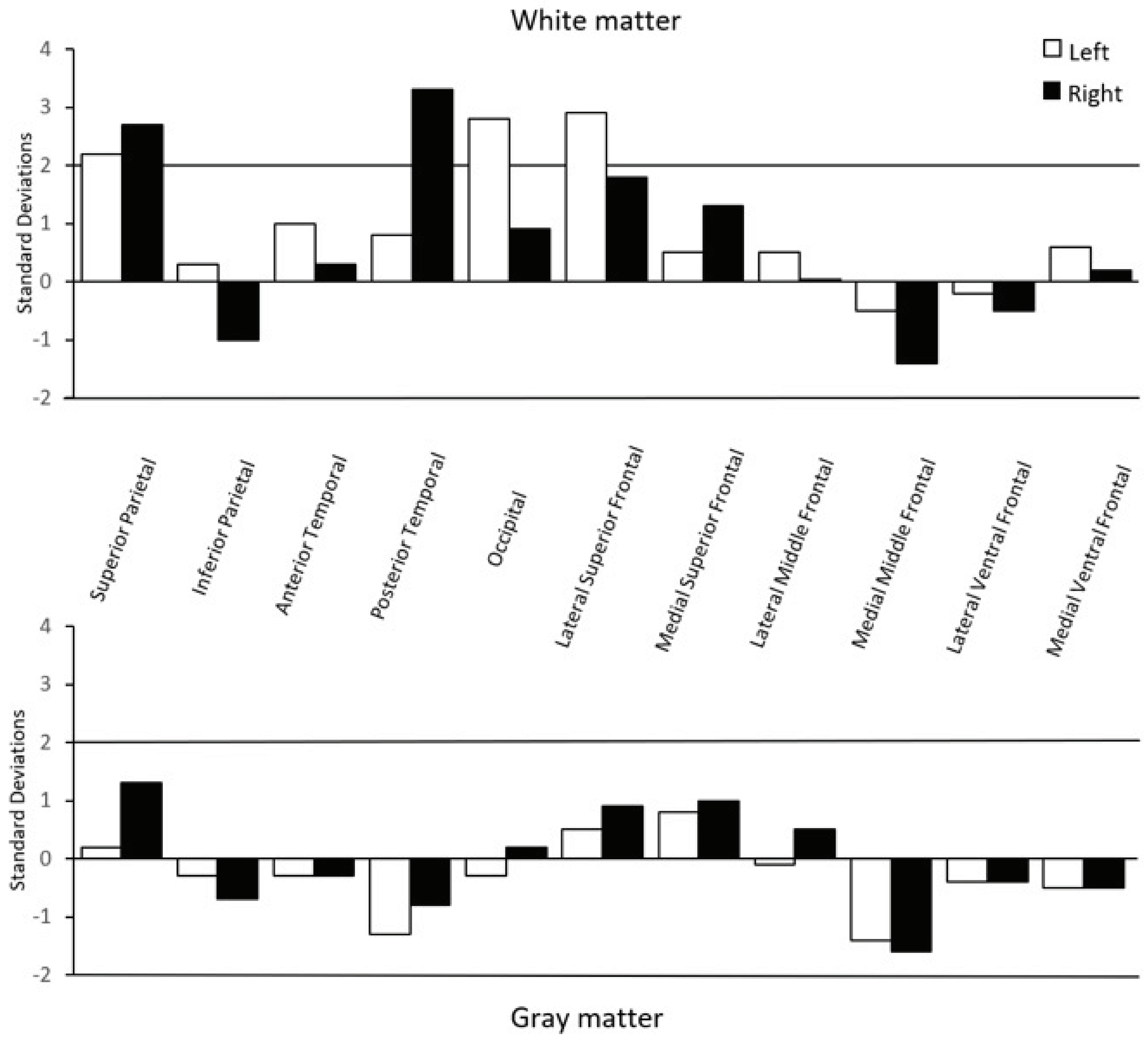


Figure 3: Bar graphs presenting (SDs) between HC brain region volumes and the mean volumes of the control group, with white matter (top) and gray matter (bottom) of the left and right hemispheres.

DISCUSSION

- The findings suggest HC's exceptional abilities may be linked to increased connectivity via WM tracts related to the cortical regions associated with visuospatial processing and mathematical cognition
- The results support the broader hypothesis that WM connectivity contributes significantly to variability in intelligence

REFERENCES

1. Witelson et al., 1999, Lancet
2. Dade et al., 2004, Neuroimage
3. Buening & Brown, 2018, Springer

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