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Sex differences in brain volume are related to specific skills, not to general intelligence

Miguel Burgaleta [a,c,*], Kevin Head [b], Juan Álvarez-Linera [c,d], Kenia Martínez [a,c], Sergio Escorial [e], Richard Haier [b], Roberto Colom [a,c]

[a] Universidad Autónoma de Madrid, Spain
[b] University of California at Irvine, USA
[c] Fundación CIEN-Fundación Reina Sofía, Madrid, Spain
[d] Ruber International Hospital, Madrid, Spain
[e] Universidad Complutense de Madrid, Spain

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ABSTRACT

It has been proposed that males would show higher mean scores than females in general intelligence (*g*) because (1) men have, on average, larger brains than women, and (2) brain volume correlates with *g*. Here we report a failure to support the conclusion derived from these premises. High resolution MRIs were acquired in a sample of one hundred healthy young participants for estimating total, gray, and white matter volumes. Participants also completed an intelligence battery – comprising tests measuring abstract, verbal, and spatial abilities – that allowed the extraction of *g* scores. Results showed consistent relations between sex differences in brain volumes and non-*g* spatial and verbal skills but not for *g*.

1. Introduction

General intelligence (*g*) is related to several factors of the human brain, such as neuronal density (Colom et al., 2009; Gläscher et al., 2010; Haier et al., 2009; Karama et al., 2009, 2011), functional efficiency (Haier et al., 1988; Neubauer & Fink, 2009; van den Heuvel, Stam, Kahn, & Pol, 2009), and integrity of brain connections (Chiang et al., 2009; Tamnes et al., 2010; Yu et al., 2008). These factors are usually explored at a regional level, most commonly through voxel-wise analyses of different modalities of magnetic resonance imaging (MRI). Nevertheless, global brain features, like total and tissue-specific volumes, have played significant roles regarding intelligence (Luders, Narr, Thompson, & Toga, 2009) and their relationships with cognitive abilities are usually easier to replicate. For instance, the meta-analysis of 37 studies (N = 1530) reported by McDaniel (2005) found an average correlation of $r = 0.33$ between in vivo estimates of total brain volume (TBV) and full-scale IQ (FSIQ). TBV might be a rough index of the total number of neurons (Pakkenberg & Gundersen, 1997) and, therefore, increased numbers of neurons may support higher intelligence.

Males have larger brains than females (Luders, Steinmetz, & Jancke, 2002) by about 10% even after controlling for body size (Rushton & Ankney, 2009). This absolute difference approximates a 16% excess in the number of neurons favoring males (Pakkenberg & Gundersen, 1997). Nevertheless, it is far from clear what males do with those extra neurons (Jensen, 1998). It has been proposed that males should outperform females on measures of *g* (Irwing & Lynn, 2009; Jackson & Rushton, 2006). Indeed, some data suggest a slight advantage for males (Lynn & Irwing, 2008; Nyborg, 2005; Rushton & Ankney, 2009), and larger male TBV is typically proposed as a potential explanation. On the other hand, most research indicates sex

* Corresponding author at: Universidad Autónoma de Madrid, 28049 Madrid, Spain. Tel.: +34 91 497 41 14.
E-mail address: miguel.burgaleta@uam.es (M. Burgaleta).

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differences in general intelligence are negligible (Aluja, Colom, Abad, & Juan-Espinosa, 2000; Brody, 1992; Colom, García, Juan-Espinosa, & Abad, 2002; Colom, Juan-Espinosa, Abad, & García, 2000; Dolan et al., 2006; Jensen, 1998; van der Sluis et al., 2006), and it has been hypothesized that the extra male brain volume might then be devoted to those specific skills in which males usually excel — mainly visuospatial abilities (Rushton & Ankney, 1996). Alternative explanations might refer to compensatory features of the female brain, such as a reportedly higher gray matter to white matter (GM:WM) ratio (Allen, Damasio, Grabowski, Bruss, & Zhang, 2003; Chen, Sachdev, Wen, & Anstey, 2007), which would allow for a reduction of neuronal wiring and an increase of the relative amount of neurons. Although there is no clear functional interpretation of this ratio (Allen et al., 2003), abnormal values of this index have been related to depression (Brambilla et al., 2001) and schizophrenia (Gur et al., 2000; Mathalon, Sullivan, Lim, & Pfefferbaum, 2001). Further, it has been suggested that a female advantage in GM:WM ratio might reflect some sort of "structural efficiency", consequence of an evolutionary adaptation to smaller cranial size, that would translate into a higher amount of "computation" rather than "information transfer" neural resources (Gur et al., 1999). However, to our knowledge there is no evidence linking individual differences in GM:WM ratio with cognitive abilities, not to mention sex differences in both aspects.

Importantly, studies suggesting a male advantage in general intelligence report differences in aggregated IQ scores, arbitrarily combining the effect of general ability and specific skills (Colom & Thompson, 2011; Colom, Karama, Jung, & Haier, 2010); *g* scores, on the other hand, allow for a more accurate measurement of general intelligence, since the contribution of specific abilities is partialled out. For example, previous studies on sex differences in regional brain volume and general intelligence (Haier, Jung, Yeo, Head, & Alkire, 2005) typically rely on a single intelligence measure that may confound *g* and other factors.

Here we addressed whether males have higher *g* scores because of their larger brains. Rejecting this proposition requires a failure to find an average sex difference in *g* in a sample where *g* correlates with TBV and where sex differences favoring males in TBV are observed. In order to gain insight into potentially significant relations, tissue-specific volumes (gray and white matter), as well as tissue ratios, were also inspected. Finally, sex differences in specific abilities and their relations to sex differences in brain volume were considered as well.

2. Method

2.1. Participants

100 young adults (44 males and 56 females; mean age = 19.88, SD = 1.67) took part in this study. Participants were Psychology undergraduates and they were tested for receiving course credit. They were screened to exclude anyone with a major medical or psychiatric illness including a history of head injury and substance abuse. Informed consent was obtained. We have previously reported other brain/intelligence results using this sample (Bruner, Martín-Loeches, Burgaleta, & Colom, 2011; Colom et al., 2009).

Body height squared (h^2) was used as a proxy for body size, following the scaling standards of the Body Mass Index (BMI = weight/height^2). Participants were asked to obtain their height from a reliable height measurement device (available in most of the Spanish drugstores) and to report it back to the researchers. Body size-corrected brain volume indices were calculated after regressing out h^2 from each volumetric index.

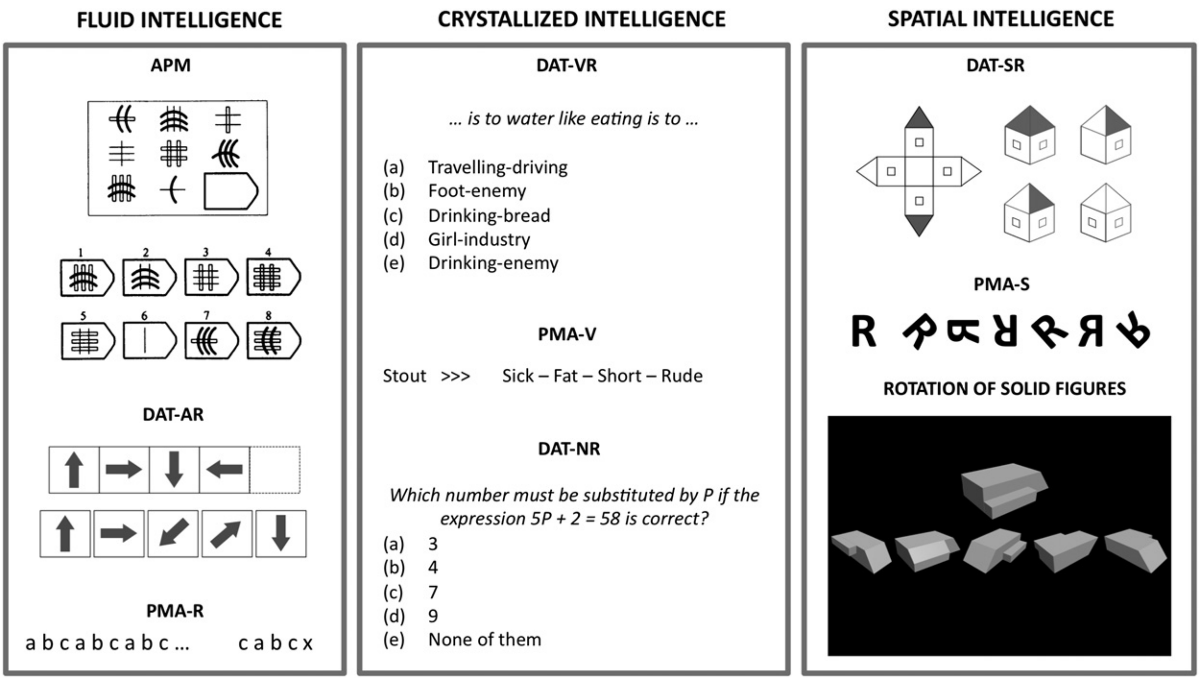

Fig. 1. Examples of items for each test.