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Research article

Association between self-reported impulsiveness and gray matter volume in healthy adults. An exploratory MRI study[☆]

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ABSTRACT

This exploratory study investigated the association between self-reported impulsiveness and cortical gray matter volume (GMV) of the entire cortex in healthy adults. As a secondary objective and based on preliminary findings concerning the positive association between self-reported impulsiveness and the slant of the forehead degrees (SFD), we analyzed associations between SFD, GMV and impulsiveness. We obtained 48 structural magnetic resonances. The participants also completed BIS 11 and profile pictures were obtained. SFD was measured by a photographic support and a protractor. The GMV of the whole cortex was obtained for each participant through Freesurfer. Firstly, we found negative and positive correlations between fronto-temporal and occipital areas respectively and BIS. Second, we found negative correlations between SFD and GMV in right postcentral gyrus, right caudal middle frontal gyrus, right transverse temporal cortex and positive correlation in left entorhinal cortex. Third, we observed a positive correlation between SFD and BIS in all impulsiveness scores. In conclusion, variations in fronto-temporal and posterior cerebral areas are crucial for BIS in healthy adults. Furthermore, SFD was associated with BIS and correlated with GMV areas involved in self-reported impulsiveness.

1. Introduction

Impulsiveness is a personality trait [1] that is generally associated with an "tendency to engage in rash actions without deliberation" [2]. Presently, it is regarded as a multidimensional psychological construct [3] and different neurobiological factors seem to be involved [4]. Therefore, there is a large body of knowledge, where different conceptualizations have arisen with some etiological controversy. [5,6].

Advances in structural neuroimaging studies suggest high implication of prefrontal cortex on behavioral control [7]. Using Voxel Based Morphometry (VBM) with healthy subjects, it has been found that orbitofrontal bilateral grey matter volume (GMV) correlated inversely with non-planning impulsiveness and motor impulsiveness from BIS, as well as, left anterior cingulate cortex with total score [8]. Other impulsiveness measures have also observed reduced orbitofrontal GMV in healthy adults [9]. Furthermore, BIS scores has been associated with a decrease in cortical thickness (CT) in the fronto-temporal areas [10,11,12]. On the other hand, positive associations had been observed in anterior cerebral areas [13,14,15].

In clinical population, structural studies have also found negative associations between impulsiveness and GMV in the orbitofrontal cortex, anterior cingulate cortex, parietal and temporal lobes [16,17]. Recently, by using BIS, its total score was associated with identified damage from multiple areas of bilateral prefrontal cortex, left superior cortex gyrus, middle and inferior temporal gyrus [18]. This reveals that solid evidence seems to suggest that fronto-temporal variations play a crucial role in impulsiveness assessed with BIS, although it is not clear the correlation of these regions with the different factors. However, there appears to be greater consistency on structural variations of the cortex in clinical subjects than in healthy subjects. Thus, our aim is to explore in healthy adults the GMV of the entire cerebral cortex to identify relevant structures associated with impulsiveness measured with BIS [19].

On the other hand, few studies have considered a relationship between craniofacial structure and self-reported impulsiveness. In this sense, two recent papers have observed a positive association between self-reported impulsiveness and the slant forehead degrees (SFD) [20,21]. Therefore, as a secondary objective based on these previous

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findings and since there are differences in the inclination of the forehead, we consider confirming this relationship in our sample. We also considered exploring the relationship between SFD and the GMV of the entire cortex, a relationship, to our knowledge it hasn't been investigated yet.

2. Material and methods

2.1. Participants

In order to recruit our sample, two advertisements were placed in training centers and libraries of Barcelona city (Spain). The sample consisted of 48 right-handed volunteers. (66.7% male) with an age mean of 36.2 years-old (SD = 9.9). Their academic level was elementary in 7 subjects (14.6%), intermediate in 16 subjects (33.3%) and high in 25 subjects (52.1%). All volunteers according to Mini-International Neuropsychiatric Interview [22] were healthy. Participants completed BIS and after that they went on to take a profile picture, whose method will be further detailed later. Finally, an appointment was made for magnetic resonance. Each participant signed an informed consent before entering the study and agreed on the use of data for research purposes. The study was approved by the Universitat Autònoma of Barcelona and followed the ethical standards defined in the Declaration of Helsinki.

2.2. Impulsiveness measurement

Barratt Impulsiveness Scale (BIS-11) [19]. The Spanish version of the instrument was applied [23]. It has 30 items scored in a Likert-type scale (0: rarely or never, 1: occasionally, 3: often, 4: always or almost always). A higher score indicates greater impulsivity. It has three subscales: attentional impulsiveness (8 items), motor impulsiveness (10 items), and non-planning impulsiveness (12 items). Internal consistency in our sample took values of Cronbach's alpha = 0.836 for the total score, and 0.476, 0.705 and 0.669 for the 3 previous subscales. In a personal communication, Barratt said the scale can be used as follows: 1 rated as 0, 2 as 1, 3 as 3, 4 as 4 (Cited in Oquendo et al. [23]).

2.3. Measurement of the slant forehead degrees

Firstly, the profile photographs were taken by a digital reflex Canon camera model EOS 1100 D EF-S 18–55. To avoid any optical distortions, the participants remained seated on a chair previously fixed to a place by the researcher. To that end, they were trained to slant their heads upwards and downwards, until they felt relaxed and adopted a natural head position (NHP) [24]. Therefore, the edge of the photograph was regarded as the true vertical (TV) and as a reference in the measurement of the SFD. The digital photographs were printed in black and white in format DIN-A4 and in vertical position. The degrees of the angle of the forehead inclination were measured by a semicircular protractor brand Staedtler 568 with a 10 cm ruler. Two anthropometric points of reference were taken from the methodology created by Farkas [25]: trichion or the point in the middle line of the forehead, which is placed in the hairline, and glabella or the point of the most prominent middle line between both eyelashes. The vertex of the angle was fixed on the glabella, from which two lines were drawn. Line 1 was vertically drawn, parallel to the edge of the photograph TV and was set as 0°. Line 2 was drawn from the glabella to the trichion. The SFD was measured as the angle, in degrees, formed by the line that goes from the glabella to the trichion (see Fig. 1). The same measurement procedure can be observed in a previous study [21]. Each participant was independently measured by three experts in craniofacial morphology. The agreement between observers was very high with intraclass correlation coefficient *CCI* = 0.99. With these results, the average of the SFD was used in posterior analyses.

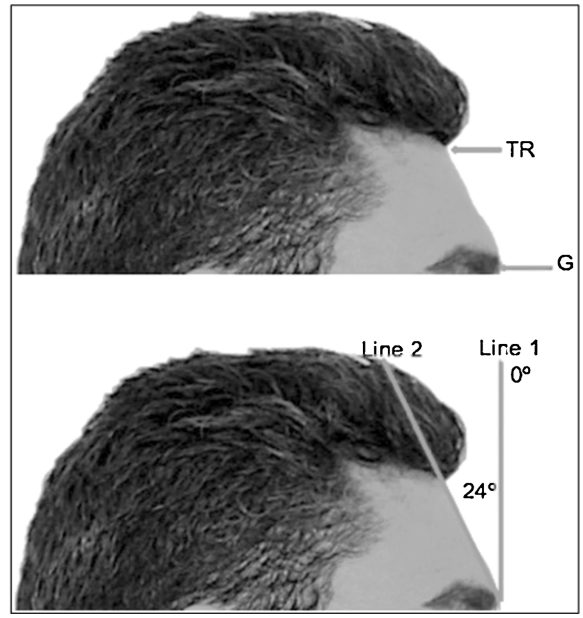

Fig. 1. Measurement of the angle of the forehead slant TR: triquion; G: glabella.

2.4. Magnetic resonance imaging acquisition

Magnetic resonance imaging (MRI) scans were obtained using 1.5 T (GE BRIVO). High-resolution 3D-FSPGR images, powered in T_1 were taken for each participant. The acquisition parameters were the following: TE = minimum; TI = 300 ms; Flip Angle = 20°; 130 adjacent axial sections; mould 256 × 256, 25 cm FoV; Slice Thickness = 1.2 mm; Receiver Bandwidth 15.63 Khz.

2.5. Structural MRI data preprocessing

Data obtained from MRI was processed using Freesurfer 5.3.0 software (http://surfer.nmr.mgh.harvard.edu). Automatic volumetry performed by Freesurfer is a quantitative measurement of specific brain regions, which has been validated in several psychiatric and neurological domains [26]. Freesurfer provides information on the following areas: frontal lobe (superior frontal gyrus, rostral and caudal middle frontal gyrus, parsopercularis, parstriangularis, and parsorbitalis gyrus, lateral and medial orbitofrontal cortex, precentral gyrus, paracentral and frontalpole), parietal lobe (superior parietal, inferior parietal, supramarginal, postcentral and precuneus), temporal lobe (superior temporal, middle and inferior temporal gyrus, banks of the superior, fusiform gyrus, transverse temporal cortex, entorhinal cortex, temporal pole and parahippocampal gyrus), occipital lobe (lateral occipital cortex, cuneus, lingual gyrus and pericalcarine cortex), cingulate cortex (rostral anterior cingulate cortex, caudal anterior cingulate cortex, posterior cingulate cortex e, isthmus cingulate cortex). In this exploratory study all areas were analyzed and all specifications about Freesurfer parcellations, including reliability, validity and anatomic limits has been described [27]. The images were visually inspected to detect structural artifacts and abnormalities, finding that none of the segmentations needed to be corrected.

2.6. Statistical analysis

Data was analyzed with Stata 14. To analyze the association between BIS and GMV and SFD adjusted Pearson correlation coefficient was calculated, previous verification of linearity of the relationships. Academic level and age were introduced in correlation analysis as adjustment terms. The *ICC* was calculated for interobserver agreement in the SFD measurement. Type I error was set at the usual 0.05 level. With