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Differential abnormalities of the head and body of the caudate nucleus in attention deficit-hyperactivity disorder

Virginia Tremols[a,b], Anna Bielsa[c], Joan-Carles Soliva[a], Carol Raheb[c], Susanna Carmona[a], Josep Tomas[c], Joan-Domingo Gispert[g], Mariana Rovira[d], Jordi Fauquet[e], Adolf Tobeña[a], Antoni Bulbena[f], Oscar Vilarroya[a,*]

[a]*Unitat de Recerca en Neurociencia Cognitiva, Departament de Psiquiatria i Medicina Legal, Universitat Autonoma Barcelona, Centre Fòrum. Hospital del Mar, Carrer Llull 410, 08019 Barcelona, Spain*
[b]*Departament de Pediatria USP Institut Universitari Dexeus, Angli 31, 08017 Barcelona, Spain*
[c]*Unitat de Paidopsiquiatria. Hospital Vall d'Hebron, Passeig de Vall d'Hebron 171, 08035 Barcelona, Spain*
[d]*CRC Corporacio Sanitaria, Barcelona, Spain*
[e]*Departament de Psicobiologia i de Metodologia de les Ciències de la Salut Universitat Autonoma Barcelona, 08193 Bellaterra, Spain*
[f]*Institut d'Atenció Psiquiàtrica, IMAS, Passeig Marítim 25-29 08003 Barcelona, Spain*
[g]*Institut d'Alta Tecnologia-Parc de Recerca Biomèdica de Barcelona, Passeig Marítim 25-29, 08003 Barcelona, Spain*

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Abstract

The aim of the study is to present a new method for the segmentation of the caudate nucleus and use it to compare the caudate heads and bodies of an attention deficit-hyperactivity disorder (ADHD) group with those of a control group. We used a 1.5-T system to acquire magnetic resonance brain scans from 39 children with ADHD, as defined by DSM-IV TR, and 39 age, handedness and IQ matched controls. The new method for caudate head and body segmentation was applied to obtain semi-automatic volumes and asymmetric patterns. Bilateral volumetric measures of the head, body, and head-body of the caudate nuclei were compared within groups and between ADHD and control groups. Although the group factor was not significant, there were first and second order interactions. The analysis of simple effects showed that the right body and right head+body of the ADHD group was significantly smaller than in the control group, although the ADHD right caudate head was bigger. No ADHD within-group caudate differences were found. Controls showed a significantly larger left caudate head and a significantly bigger caudate right body and right head+body. Our new method for segmenting the caudate nucleus detected differential abnormalities of the right caudate head and body in the ADHD group, explaining previous heterogeneous findings in the literature.

Keywords: ADHD; MRI; Caudate nucleus; Morphometry; Volumetry

1. Introduction

The caudate nucleus is a critical brain region implicated in the pathophysiology of attention deficit-hyperactivity disorder (ADHD) (Barkley, 1997; Sergeant, 1990; Swanson et al., 1998). Structural neuro-

* Corresponding author. Tel.: +34 932 541 313; fax: +34 932 541 315.
E-mail address: oscar.vilarroya@uab.es (O. Vilarroya).

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imaging studies have confirmed abnormalities in such a structure in ADHD patients, though with somewhat conflicting results. In caudate-nuclei morphometry studies, some authors found that ADHD populations had a smaller left caudate head (Filipek et al., 1997; Hynd et al., 1993; Semrud-Clikeman et al., 2000) in comparison with control samples. One study showed a left caudate total volume reduction (Filipek et al., 1997), while the study with the largest ADHD sample (Castellanos et al., 1996) found smaller right total caudate volumes in comparison with control samples. In intragroup comparisons, the ADHD population was found to present a right-caudate head asymmetry (right bigger than left) (Hynd et al., 1993) and total right caudate asymmetry, while the largest sample study (Castellanos et al., 1994, 1996) found a total caudate symmetry. In addition, another study (Schrimsher et al., 2002) found that a greater degree of right caudate asymmetry predicted subclinical inattentive behaviour in the general population.

Such discordant results may in part stem from methodological differences. Some studies use automatic measures, and others apply manual techniques. The studies using automatic techniques lack a standard method to segment automatically the brain structures implicated in the disorder, and the manual techniques have not provided a clear way of establishing the frontier between the caudate head and body. Besides, the samples, with the exception of those of Castellanos (Castellanos et al., 1994, 1996), Hill (Hill et al., 2003) and Durston (Durston et al., 2004) are rather small.

Two points are critical to confirm or disprove the results obtained so far in caudate nuclei. Firstly, manual measures are required to complement the automatic methods employed and, secondly, the size of the sample studied must be increased. There is nevertheless an additional point that may be more critical to detect specific abnormalities. One important difference among extant studies is between those that measure the caudate nucleus *in toto*, and those that segment the head and the rest of the nucleus. In our opinion, the measures of total caudate volumes may screen off differential abnormalities of the caudate head and body.

The fact is that the head, body and tail of the caudate nucleus seem to participate in different pathways, and hence in different functions. The caudate head is integrated in the dorsolateral prefrontal, lateral orbitofrontal and anterior cingulate circuits of Alexander (Alexander et al., 1986). The body of the caudate is integrated in Alexander's oculomotor circuit. Functionally, the head of the caudate nucleus has been related to multi-modal information and inhibition processes. Lesions in the head of the caudate nucleus can result in sensory neglect, agitation, hyperactivity, distractibility and, in some cases, manic or schizo-affective psychosis (Aylward et al., 1996; Caplan et al., 1990; Castellanos et al., 1994; Richfield et al., 1987). In recent studies, the head of the caudate nucleus has been associated with feedback processing, while the caudate body has been implicated in successful classification learning (Seger and Cincotta, 2005).

Therefore, if the striatal pathway is dysfunctional in ADHD, and this dysfunction affects in different ways the head and the body of the caudate nucleus, then there may be morphometric abnormalities in the disorder showing a differential implication of each of these caudate areas. However, there is no extant method for segmenting the caudate head from the body. The aim of this study is to introduce a caudate segmentation method and to use it to compare the caudate heads and bodies of an ADHD group with those of a control group.

2. Methods

2.1. Participants

The study population (Table 1) included 39 children (35 boys and 4 girls) with ADHD according to DSM-IV

Table 1
Sample

	n	Sex	Age (years) mean±S.D.	Handedness [a]	Type	MPH mean±S.D.	CBCL Hyperactivity mean±S.D.
ADHD	39	Boys=35 Girls=4	10.8±2.9	R=27; L=4; CD=8	I=8 H-I=7 C=24	0.6±0.05	73.3±10.3
Control	39	Boys=27 Girls=12	11.7±2.9	R=27; L=3; CD=9	NA	NA	56.3±3.4

I=Inattention subtype; H-I=Hyperactive-impulsive subtype; C=Combined subtype. R=right-handed; L=left-handed; CD=cross-dominance. MPH (mg/kg)=methylphenidate. NA=not applicable. CBCL: Child Behavior Checklist (ages 6 to 16 years).

[a] Handedness measured with a battery that includes Piaget's Test, Head's Test and Nadine Galifrast–Granjon's Test.