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What does handedness reveal about ADHD? An analysis based on CPT performance

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ABSTRACT

Background: Attention-deficit/hyperactivity disorder (ADHD) is a developmental disorder. Continuous performance Tests (CPTs) aid the diagnosis. Handedness is linked to disabilities.
Objectives: 1-To study the association between handedness and ADHD; 2-To verify the usefulness of the CPT in school settings; 3-To exam the relationship between handedness and CPT performance.
Method: Each child was classified as right-consistent, left-consistent, or non-consistent. From the sample, 171 controls and 68 ADHDs fulfilled the inclusion criteria. The effect of handedness on the CPT was studied using a paired-sample that matched handedness by age, grade, gender, and ADHD.
Results: Left-handed students had a probability of suffering from ADHD 2.88 greater than right-handers. ANOVAs on standardized scores indicated that the ADHD students exhibited higher number of errors and higher variability of reaction times as compared to the controls. Discriminant analysis indicated that these CPT parameters could discriminate ADHD from controls. Repeated ANOVAs showed a significant effect of handedness on commission errors (CE) because left-handers made more CEs than right-handers.
Conclusions: 1-The association between ADHD and handedness reflects that left-handers are less lateralized and have decreased interhemispheric connections; 2-The CPT can be used to measure different attention domains in school settings; 3- Left-handers have problems in the impulsive/hyperactivity domain.

What this paper adds?

Gender and handedness are associated with several developmental disorders, which has led to many implications for understanding these diseases and their problems' remediation. Attention-deficit/hyperactivity disorder (ADHD) is an early-onset disease affecting 5% of the population worldwide. Gender and age differences are known to be associated with ADHD. Regarding handedness, the data are controversial. Here, for the first time in ADHD studies, handedness was defined by direction and strength. The diagnosis of ADHD was based on clinical analysis with the aid of the DSM-V. We found a significant prevalence of 12% consistent left-handed(CLH) among the ADHD children compared to controls (4%). The distinct components of attention were assessed with a

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Continuous Performance Test (CPT). Using standardized scores, we found that inattention, impulsivity, and sustained attention could be measured by independent CPT variables. The relationship between these variables and handedness was studied using a matched-paired design, which required a small number of CLH children. The minimum number of subjects was calculated considering an effect size that is psychologically meaningful and was based on a previous test-retest reliability study. CLH children were found to be more impulsive than right-handers. Our data suggested that impulsivity is associated with abnormal brain laterality and with abnormal interhemispheric connections. Consistency of handedness is important because it refers to the callosal connections, whereas direction refers to brain lateralization. Norms derived from CPTs must be interpreted with caution, especially when CLHs are being tested. The present findings have implications for the understanding of this highly prevalent developmental disorder.

1. Introduction

1.1. ADHD, brain abnormal laterality, and callosal interhemispheric connections

Attention-deficit/hyperactivity disorder (ADHD) refers to an early-onset highly prevalent developmental disorder, with an estimated worldwide prevalence of approximately 5% (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014). It is characterized by age- inappropriate levels of inattention, motor hyperactivity, and impulsivity, that cause significant interference in at least two environments, such as, social life and academic functioning (American Psychiatric Association, 2013). Genetic and environmental factors are implicated with the etiology of this disease (Shang & Gau, 2014; Willcutt et al., 2011) but the physiopathology of ADHD is not fully understood (Cortese, 2012). In this regard, several investigators have proposed that atypical brain laterality is a core component of this disease (Hale, Brokheimer, McGough, Phillips, & McCracken, 2007; Hale et al., 2014; Silk et al., 2016).

Abnormal brain laterality is implicated with other psychiatric illness, such as, autism (Floris et al., 2016), and anxiety (Bruder et al., 2015). The first indication of abnormal brain laterality in ADHD stemmed from observations that unilateral right-sided brain damage produced symptoms reminiscent of this disease (Heilman, Bowers, Valenstein, & Watson, 1986). Previous studies have suggested that ADHD is, at least in part, related to a right hemisphere dysfunction (e.g., Sandson, Bachna, & Morin, 2000). More recently, ADHD was associated with anomalous hemispheric asymmetries in major fibre tracts of the frontostriatal system (Silk et al., 2016). Alteration of the right superior longitudinal fasciculus has also been demonstrated in children and adults with ADHD (Chiang, Chen, Lo, Tseng, & Gau, 2015).

Several studies have reported that the development of the corpus callosum is associated with the establishment of brain asymmetries (e.g., Lent & Schmidt, 1992). Callosal abnormalities have been described in ADHD (e.g., Semrud-Clikeman et al., 1994). A previous study reported that disrupted callosal growth is related to the abnormalities in development of prefrontal cortex asymmetry and concluded that abnormalities in interhemispheric connections are found in ADHD patients (Gilliam et al., 2011). The question that remained to be clarified is the possible relationship between brain laterality and handedness as well as between handedness and ADHD.

1.2. Handedness as a proxy to cerebral asymmetries: relationship with ADHD

Humans show a strong bias toward using one hand rather than the other for manual activities. In fact, roughly 90% of humans are right-handed (Ellis, Ellis, & Marshall, 1988). The preference most people show in using one hand over the other to perform motor tasks must originate in the cerebral cortex (McManus, 1984). There are several examples of cerebral lateralization of cognitive functions such as language and visuospatial skills (Groen, Whitehouse, Badcock, & Bishop, 2012). It is well known that over 90% of right-handers have language skills lateralized to the left hemisphere (Knecht et al., 2000; Mellet, 2014). Thus, handedness is considered as an indirect measure of cerebral asymmetry and is commonly used as a proxy for cerebral lateralization because it is a cheap and easy measure.

Departures from right-handedness have been linked to disabilities, such as, schizophrenia (Hirnstein & Hugdahl, 2014), dyslexia (Brandler & Paracchini, 2014), autism (Lindell & Hudry, 2013), and stuttering (Kushner, 2012). Concerning ADHD, the data are highly controversial. A previous study reported that ADHD was not exclusively related to the prevalence of non-right-handedness (Reid & Norvilitis, 2000). In contrast, other investigators found a higher than expected proportion of left-handedness in children with ADHD (Rodriguez & Waldenström, 2008). Another study reported that mixed- handedness was associated to increased risk for ADHD (Rodriguez, Kaakinen, Moilanen, Taanila, & McGough, 2010). More recently, it was reported that left-handedness was not associated with higher parent-reported ADHD (Ghanizadeh, 2013). Part of the controversy may be related to the definition of handedness. As ADHD is related to both abnormal brain laterality (Hale et al., 2009) and disrupted interhemispheric connections (Gilliam et al., 2011), the definition of handedness should consider these two factors.

1.3. Definition of handedness

Different approaches have been taken to measure hand preference, ranging from motor performance measurements to self-report inventories assessing hand choice across various manual activities (Oldfield, 1971). Brain asymmetries may be indirectly assessed by the direction of handedness since left-handers exhibit less cerebral asymmetry and more abnormal brain laterality than right-handers (Bishop, 1990; Schmidt, Oliveira, Rocha, & Abreu-Villaça, 2000).

However, ADHD is related not only to abnormal brain laterality but also to callosal connections (Gilliam et al., 2011). Therefore, simply classifying the subjects into left or right-handers seems to be insufficient to clarify the controversy regarding handedness and