Research in Autism Spectrum Disorders 8 (2014) 387–412

Contents lists available at ScienceDirect

Research in Autism Spectrum Disorders

Journal homepage: http://ees.elsevier.com/RASD/default.asp

Review

Autism as a disconnection syndrome: A qualitative and quantitative review of diffusion tensor imaging studies

Margot Hoppenbrouwers [a], Maaike Vandermosten [b], Bart Boets [a,c,*]

[a] Child and Adolescent Psychiatry, University of Leuven (KU Leuven), Herestraat 49, Box 7003, 3000 Leuven, Belgium
[b] Centre for Parenting, Child Welfare & Disabilities, University of Leuven (KU Leuven), Leopold Vanderkelenstraat 32, Box 3765, 3000 Leuven, Belgium
[c] Leuven Autism Research Consortium, University of Leuven (KU Leuven), 3000 Leuven, Belgium

ARTICLE INFO

Article history:
Received 25 September 2013
Received in revised form 20 December 2013
Accepted 26 December 2013

Keywords:
Autism spectrum disorder
Diffusion tensor imaging
Review
Brain connectivity
Fibre tracking

ABSTRACT

This review aims at evaluating the leading hypothesis of lower long-range and greater short-range cortical connectivity in individuals with autism spectrum disorder (ASD) by the available literature on diffusion tensor imaging (DTI) studies. DTI, coupled with tractography, assesses the structural connections between cortical regions and quantifies their white matter integrity. First, we provide an extensive qualitative overview of DTI findings in ASD. Next, to reveal convergence between studies, results are quantitatively analyzed using Activation Likelihood Estimation (ALE) and fibre tracking is performed to visualize the white matter tracts running through the obtained ALE clusters. Finally, findings from DTI research are related to specific symptoms characteristic of ASD. Overall, the qualitative analysis yields a widespread disruption of white matter integrity in the brain of individuals with ASD as compared to typically developing controls. This is the case for both the long-range and the local short-range connections, partially contradicting the leading hypothesis. However, several studies investigating very young children with ASD report greater structural connectivity, suggesting a developmental switch in white matter integrity in the ASD brain. Based on the combined qualitative and quantitative analysis, the corpus callosum and the ventral tracts emerge as particularly affected connections in individuals with ASD.

Contents

* Corresponding author at: Child and Adolescent Psychiatry, University of Leuven (KU Leuven), Herestraat 49, Box 7003, 3000 Leuven, Belgium. Tel.: +32 16 34 25 03; fax: +32 16 34 38 30.
E-mail address: bart.boets@ppw.kuleuven.be (B. Boets).

1750-9467/$ – see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rasd.2013.12.018

1. Introduction

1.1. Autism spectrum disorders

Autism spectrum disorder (ASD) refers to a continuum of early onset pervasive neurodevelopmental disorders, characterized by deficits in social reciprocal interactions and communication, as well as a restricted, repetitive pattern of interests and behaviour (American Psychiatric Association (APA), 2000, 2013; Huerta, Bishop, Duncan, Hus, & Lord, 2012). The disorder is heterogeneous and the quality and extent of the symptoms vary widely (Geschwind & Levitt, 2007). Since the recent implementation of the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (APA, 2013), ASD comprises a single diagnostic category instead of the collection of several distinct disorders (Huerta et al., 2012).

Research shows a sharp increase in the number of ASD publications during the last fifteen years, especially studies concerning the underlying biology of ASD. However, the numerous attempts to unravel the aetiology and possible biological determinants of ASD did not yet result in a coherent and unifying theory. An improved comprehension of the neurobiological basis of the disorder may contribute to new insights into detection, treatment and prevention (Verhoeven, De Cock, Lagae, & Sunaert, 2010).

1.2. Lower long-range and greater short-range connectivity

Aberrant brain development in the pathogenesis of ASD is widely accepted. Former neuroimaging research focused on the association between localized neurological impairments and the symptom profile of ASD (Müller, 2007). Publications in the last decade also revealed widespread abnormalities in functional and structural networks in addition to localized abnormalities (Geschwind & Levitt, 2007; Just, Cherkassky, Keller, & Minshew, 2004; Müller, 2008). One of the leading hypotheses in the neuroimaging research suggests a combination of lower long-range and greater short-range connectivity in people with ASD (Barttfeld et al., 2011; Belmonte et al., 2004; Wass, 2011). This hypothesis has its origin in the underconnectivity theory of Just et al. (2004). The latter is based on the clinical expression of ASD, including a variety of problems (e.g. social interaction, communication, theory of mind, executive functioning, etc.; Bauman & Kemper, 2003; Happé, 1999), all requiring higher-order processing in the brain. Just et al. (2004) presume that in ASD "...any facet of psychological or neurological function that is dependent on the *coordination* or *integration* of brain regions is susceptible to disruption, particularly when the computational demand of the coordination is high" (Just et al., 2004, p. 1817). This theory of *underconnectivity* provided a biological basis for the weak central coherence theory, formulated by Frith (1989) (Brock, Brown, Boucher, & Rippon, 2002; Just et al., 2004). Frith (1989) suggested that subjects with ASD show an excessive focus on details at the expense of developing a more integrated representation of incoming information (Just et al., 2004). In addition to the theory of underconnectivity, some researchers suggested the presence of *greater connectivity* in the ASD brain (Rubenstein & Merzenich, 2003). According to the enhanced perceptual functioning (EPF) model, greater connectivity within local perceptual regions, along with lower connectivity between perceptual regions and other parts of the brain, might result in highly specialized networks in the ASD brain. These networks could account for the prevalence of superior perceptual performance, as sometimes observed in people with ASD (Mottron, Dawson, Soulières, Hubert, & Burack, 2006; Mottron et al., 2013). The combination of the under- and overconnectivity theory, together with the observed impairments in integration and coordination, and the outstanding isolated (savant) capacities of some people with ASD, ultimately resulted in the leading hypothesis of greater short-range and lower long-range connectivity (Belmonte et al., 2004; Just et al., 2004).