Research in Developmental Disabilities 47 (2015) 234–283

Contents lists available at ScienceDirect

Research in Developmental Disabilities

Review article

A systematic review of mirror neuron system function in developmental coordination disorder: Imitation, motor imagery, and neuroimaging evidence

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ARTICLE INFO

Article history:
Received 7 April 2015
Received in revised form 15 September 2015
Accepted 16 September 2015
Available online 23 October 2015

Keywords:
Developmental coordination disorder
DCD
Mirror neuron system
Imitation
Motor imagery

ABSTRACT

PURPOSE: The aim of this systematic review was to investigate the evidence of abnormal functioning of the mirror neuron system (MNS) in children and adults with developmental coordination disorder (DCD), through examination of imitation, motor imagery, and neuroimaging literature.
METHODS: The following databases were comprehensively searched for relevant articles: CINAHL Plus, Embase, MEDLINE, PsycINFO, Pubmed, and Web of Science. Full-text articles of all potentially relevant citations were obtained and assessed for eligibility by two authors. Outcome measures of interest at a motor behaviour level were any measures of imitation or motor imagery proficiency and, at a neurological level, were any measures of neural activity in MNS brain regions. Due to differences in outcome measures between studies and the variables reported, a narrative review was undertaken to synthesise findings from the studies.
RESULTS: Overall, 31 articles met the inclusion criteria. Children and adults with DCD display deficits imitating meaningful and novel gestures and demonstrate different response patterns to controls when undertaking complex motor imagery tasks. Children with DCD present reduced activation and connectivity of frontal, parietal, and temporal MNS regions.
CONCLUSIONS: Preliminary evidence indicates some deficit in the functioning of the MNS at a motor behaviour and neurological level. As no published neuroimaging studies have been designed specifically to explore MNS function, these results must be interpreted with caution. Further research to explore the MNS hypothesis in greater detail, particularly from a neuroimaging perspective, has the potential to provide information on the underlying mechanisms of DCD, inform future research into the aetiology of this disorder, and inform intervention approaches.

Abbreviations: BOLD, blood–oxygen-level dependent; DCD, developmental coordination disorder; pDCD, probable developmental coordination disorder; DSM-5, Diagnostic and Statistical Manual of Mental Disorders; DTI, diffusion tensor imaging; EEG, electroencephalography; fMRI, functional magnetic resonance imaging; IFG, inferior frontal gyrus; IPL, inferior parietal lobule; M1, primary motor cortex; MNS, mirror neuron system; ROI, region of interest; rsfMRI, resting state functional magnetic resonance imaging; STS, superior temporal sulcus.

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http://dx.doi.org/10.1016/j.ridd.2015.09.015
0891-4222/

Contents

1. Introduction

Developmental coordination disorder (DCD) is a condition characterised by impaired motor coordination and an inability to perform and learn motor skills at an age appropriate level (American Psychiatric Association [APA], 2013). DCD is one of the most common childhood developmental disorders, affecting approximately 6% of school-aged children (APA, 2013; World Health Organisation [WHO], 2010). The poor motor performance displayed by children with DCD may present as persistent difficulty acquiring basic motor skills such as running, throwing, and catching, poor balance, and postural control, as well as difficulties associated with daily activities including tying shoelaces and handwriting (APA, 2013; Geuze, 2005; Wilson, Ruddock, Smits-Engelsman, Polatajko, & Blank, 2013). In addition to the impaired fine and gross motor coordination experienced, individuals with DCD show marked neurodevelopmental immaturities and neurological soft signs, including choreiform and mirror movements (APA, 2013; WHO, 2010). Children with DCD experience activity limitations and participation restrictions at home, school, and in the community, significantly impacting their emotional and social development, and placing them at greater risk for depression, anxiety, and low self-esteem (Jarus, Lourie-Gelberg, Engel-Yeger, & Bart, 2011; Pratt, & Hill, 2011; Zwicker, Harris, & Klassen, 2013).

DCD is classified under the Motor Disorders subcategory of Neurodevelopmental Disorders in the Diagnostic and Statistical Manual of Mental Disorders (5^{th} ed.; DSM-5) (APA, 2013), and as Specific Developmental Disorder of Motor Function (F82) which falls under Pervasive and Specific Developmental Disorders, a subcategory of Developmental Mental, Behavioural and Neurodevelopmental Disorders in the International Classification of Diseases framework (WHO, 2010). Whilst by its definition, no identifiable hard neurological signs are associated with DCD, it has long been suspected that the motor difficulties experienced are neurologically based (Brown-Lum & Zwicker, 2015; Debrabant, Gheysen, Caeyenberghs, Van Waelvelde, & Vingerhoets, 2013; Kashiwagi, Iwaki, Narumi, Tamai, & Suzuki, 2009; Langevin, MacMasters, Crawford, Lebel, & Dewey, 2014; Langevin, MacMaster, & Dewey, 2015; Licari et al., 2015; McLeod, Langevin, Goodyear, & Dewey, 2014; Querne et al., 2008; Zwicker, Missiuna, Harris, & Boyd, 2010, 2011, 2012). Very little is known about the underlying aetiology, as limited neuroimaging studies have been undertaken to examine the suspected deficits in neurological functioning of this population. As a result, to date, hypotheses regarding the neural correlates of DCD have typically been drawn from behavioural studies. With advancements in technology, recent research has utilised neuroimaging techniques such as functional magnetic resonance imaging (fMRI) (Debrabant et al., 2013; Kashiwagi et al., 2009; Licari et al., 2015; Querne et al., 2008; Zwicker et al., 2010, 2011), resting state fMRI (rsfMRI) (McLeod et al., 2014), and diffusion tensor imaging (DTI) (Langevin et al., 2014; Zwicker et al., 2012) to examine areas of potential neurological dysfunction.

A recent meta-analysis undertaken by Wilson et al. (2013) highlights the extensive range of difficulties children with DCD experience. Seven main task category clusters of movement deficits were identified, including the domain general clusters: internal (forward) modelling, rhythmic coordination, and executive function, and the domain-specific: control of gait and posture, control of reaching, catching and manual interception, and aspects of sensoriperceptual function. A separate meta-analysis suggests that children with DCD also have underlying visuo-motor translation deficits (Blank, Smits-Engelsman,