

Developmental coordination disorders and sensory processing and integration: Incidence, associations and co-morbidities

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British Journal of Occupational Therapy
2017, Vol. 80(9) 549–557
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sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0308022617709183
journals.sagepub.com/home/bjot


Abstract

Introduction: Children with developmental coordination disorder or sensory processing and integration difficulties face challenges to participation in daily living. To date there has been no exploration of the co-occurrence of developmental coordination disorders and sensory processing and integration difficulties.

Method: Records of children meeting *Diagnostic and Statistical Manual – V* criteria for developmental coordination disorder ($n = 93$) age 5 to 12 years were examined. Data on motor skills (Movement Assessment Battery for Children – 2) and sensory processing and integration (Sensory Processing Measure) were interrogated.

Results: Of the total sample, 88% exhibited some or definite differences in sensory processing and integration. No apparent relationship was observed between motor coordination and sensory processing and integration. The full sample showed high rates of some difficulties in social participation, hearing, body awareness, balance and motion, and planning and ideation. Further, children with co-morbid autistic spectrum disorder showed high rates of difficulties with touch and vision.

Conclusion: Most, but not all, children with developmental coordination disorder presented with some difficulties in sensory processing and integration that impacted on their participation in everyday activities. Sensory processing and integration difficulties differed significantly between those with and without co-morbid autistic spectrum disorder.

Keywords

Developmental coordination disorder, sensory integration, participation, autistic spectrum disorder

Received: 6 August 2016; accepted: 10 April 2017

Introduction

Developmental coordination disorder (DCD) is described as a developmental motor disorder that impacts on performance in everyday life. For most, DCD and its consequences have a long-term impact. This may include reduced participation in self-care, leisure or academic activities, as well as higher rates of cardiovascular disease and challenges to mental health (Cairney, 2015). The Royal College of Occupational Therapists (COT, 2015) advocates that occupational therapy intervention not only reduces long-term costs, but also improves strategies to master skills important to the individual, facilitates social and physical participation and creates a more supportive environment for the child and family. Conversely, if challenges remain unaddressed there is high risk of negative impact on education, social participation, mental health, participation in daily living skills and quality of life/life satisfaction. Planned intervention should take account of personal and environmental factors as well as the burden of disease on participation (Blank et al., 2012).

One factor that impacts interaction of the individual, their interaction with the environment and successful participation is sensory processing and integration. No data

are currently available to quantify the level of sensory processing and integration difficulties in the population of children with DCD. The aim of this study is to identify the incidence of sensory processing and integration difficulties in children with DCD. It is also to explore possible correlations between motor and sensory skills and to consider whether additional co-occurring conditions demonstrate different patterns of difficulties in sensory processing and intervention. This may improve understanding, assist in skill development and increase participation. Greater understanding of DCD and related sensory processing and integration difficulties has the potential not only to assist with accurate diagnoses, but also to direct and focus future evaluation of intervention in both health

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and educational settings, working towards improving quality of life for children and their families. This study gives a clinical perspective on the extent of sensory processing and integration difficulties in children with DCD.

Literature review

Children with DCD are recognised as having challenges in everyday activities, school performance and social participation. They are commonly referred to occupational therapy services to address these challenges (Blank et al., 2012). DCD is described as a condition marked by motor skills that are below those expected at a given chronological age when the opportunity is presented for skill learning and use. These motor skill deficits significantly or persistently interfere with the activities of daily life and impact academic/school productivity, leisure and play. Presenting difficulties are not due to a general medical condition (for example, cerebral palsy, muscular dystrophy or degenerative disorder), intellectual impairment or a visual deficit (American Psychiatry Association, 2013).

DCD impacts the health and wellbeing of the child, along with participation in daily life, with an ensuing impact on the family (Tal-Saban et al., 2014). It affects between 1.8% and 4.8% of the childhood population, with a boy to girl ratio of 1.9 to 1 (Lingam et al., 2009), although some researchers suggest this may be a conservative estimate of incidence (Blank et al., 2012). Intervention by occupational therapists or physiotherapists is advocated, but no single approach to intervention has been fully substantiated (Zwicker et al., 2012). There is emerging support for task-specific interventions, but this approach is less accessible to younger children and to those with additional impairments such as language, communication or possible sensory processing and integration difficulties. While a graded approach to service provision has been advocated, it is still acknowledged that more research is needed, comparing types of intervention and models of service delivery (Camden et al., 2014). It is imperative for therapists and researchers to continue exploring both the factors that impact participation and the best ways to meet the individual needs of the child and family.

There is evidence to suggest performance deficits impact motor skill development and consequently participation. Through a meta-analysis of performance factors, Wilson et al. (2012) identified deficiencies in internal (forward) modelling, rhythmic coordination, executive function (including working memory, inhibition and attention), gait and postural control, catching and interceptive action, and aspects of sensory perceptual control. According to Wilson et al. (2012), children with DCD appear to have an internal modelling deficit or difficulty generating and monitoring internal models of movement.

Other researchers have explored the link between the ability to process sensory information and motor skills. Poorer function in visual motor and visual perceptual skills, tactile sensitivity, organisation of visually perceived

information, proprioception, vestibular function and visuomotor skills have been noted in children with DCD (Goyen et al., 2011; Loh et al., 2011).

Researchers have also explored the neural correlates of coordination difficulties. Zwicker et al. (2010) identified under-activation in the cerebellar-parietal and cerebellar prefrontal networks, and increased activation in brain regions associated with visuospatial learning. Despite visuospatial deficits noted in children with DCD (Goyen et al., 2011; Loh et al., 2011), visuospatial skills were heavily utilised by children in this study. Zwicker et al. (2010) proposed that deficits in somatosensory feedback may be linked to increased dependence on visual and spatial processing as well as attention and memory for motor learning.

King et al. (2011) took a novel approach to analysing data on sensorimotor functioning by considering both intra- and inter-individual variability. Children with DCD and a group of typically developing children completed a motor-tracking task from a vertical computer monitor to their own hands, while their hands were obscured beneath the screen. While children with DCD showed greater variability of response, their mean scores did not differ significantly from typically developing controls. It was suggested that initial motor learning was adequate but long-term sensorimotor retention was impaired. Having an accurate internal model is dependent on the quality of sensory information coming into the central nervous system. It then relies on that information being effectively collated and stored, and finally on the information being retrieved in a timely manner to support forward planning. Sensory processing and integration is one component that, along with attention, cognition and motor skills, supports self-regulation and organisation of movement and behaviour.

These studies give evidence of sensory issues being present in children with DCD. They also underline that sensory processing and integration difficulties impact everyday movement, behaviour and learning. More specifically, sensory processing and integration difficulties have a negative effect on family participation (Bagby et al., 2012) and on child participation in areas of self-care, school work and social interaction (Dunn et al., 2016).

White et al. (2007) identified a specific relationship between activities of daily living, gross and fine motor skills, perceptual skills, sensory sensitivity, low endurance/tone and modulation factors. The high levels of co-morbidity in sample groups suggests that difficulties in occupational performance are linked to a combination of factors rather than sensory processing and integration issues alone.

It is noteworthy that while there is evidence of an association between sensory processing and integration difficulties and some developmental disorders such as autistic spectrum disorder (ASD) (Adamson et al., 2006), a specific link has not been established in children with DCD.

There is an ongoing debate over the classification and diagnostic criteria associated with sensory processing and integration issues, and the terms 'sensory processing

disorder' and 'sensory integration dysfunction' are sometimes used interchangeably (Dunn, 1997; Miller et al., 2007; Schaaf and Davies, 2010). It is beyond the remit of this paper to explore this debate. However, in line with the assessment tools selected and acknowledging current work (Schaaf and Mailloux, 2015), the term 'sensory processing and integration difficulty' will be used here to describe problems experienced by children with modulating, discriminating and motor planning/praxis using sensory information, and the impact these problems present for everyday functioning and participation. The model of sensory integration is based on the work of A. Jean Ayres and is described most recently in the work of Bundy et al. (in press).

The purpose of this study was to determine if children with DCD present with sensory processing and integration difficulties.

The research questions were:

1. Do children with DCD have sensory processing and integration difficulties?
2. Is there an association between reported sensory processing and integration difficulties and DCD?
3. Is sensory processing and integration the same in children with and without co-occurring conditions?

Method

Research was conducted in a Specialist Child Development Centre in a south of England health trust covering rural and metropolitan areas with a mixed socioeconomic profile. The United Kingdom National Health Service provides a 'free at the point of access' service. The occupational therapy service provided the primary assessment service for the area. Ethical permission was granted by the University, National Research and Hospital Trusts ethical committees. Data collection sheets were given a unique identifier code. Codes were stored against names of children, on a separate document in a locked filing cabinet in the Children's Centre to ensure confidentiality. As data collection was retrospective and anonymised, individual written consent was not required by the ethical committees.

Population

Inclusion criteria included the age range of children from five to 12 years who met the criteria for DCD as stated in the European Academy of Childhood Disability (EACD) guidelines (Blank et al., 2012) and DSM-5 (American Psychiatric Association, 2013). Movement Assessment Battery for Children (MABC-2) (Henderson et al., 2007) scores were at or below a standard score of 6 (below 15th percentile), with functional impairment in self-care or school skills. Only children attending mainstream schools were included, to exclude those with recognised learning disability. In keeping with these criteria, children with comorbid developmental disorders (such as ASD) and attention deficit disorders (ADD) were included. Children with neurological impairment, such as cerebral palsy, were

excluded. The population of children between age five and 12 years in the geographical area of the trust was estimated to be 45,600 (CHIMAT, 2012). The reported prevalence of DCD is 1.8%–4.8% (Lingam et al., 2009). At the higher rate of incidence, the expected number of children with DCD age five to 12 years would be as many as 2234. The required sample size, calculated with the Raosoft power calculator (Raosoft, 2004), was 93 (95% confidence interval and 10% margin of error).

Data collection

Data were collected pragmatically through a retrospective interrogation of case notes from 2011 to 2013. Cases were selected based on inclusion and exclusion criteria. Only children who fell on or below a total standard score of 6 in the total MABC-2 were included in the study. Data were collected for age, gender, reason for referral, functional difficulties, co-morbid diagnosis (as diagnosed by a community paediatrician, psychologist or psychiatrist), full and subsection scores on MABC-2 and the Sensory Processing Measure Home form (SPM) (Parham et al., 2007). Both the SPM and MABC-2 were used at the point of intake into occupational therapy services.

Measures

The two variables under consideration were motor coordination and sensory processing and integration. The independent variable was motor coordination as measured by MABC-2 full scores and subsection scores. This is a norm-referenced assessment completed by the child and scored by the occupational therapist. MABC-2 is divided into three sections: manual dexterity, aiming and catching, and balance. Inter-rater reliability is between 0.94 and 1.00. Test-retest reliability is good, and the intra class coefficient was 0.88 with a 95% confidence interval of 0.79 to 0.93 (Van Waelvelde et al., 2007). There is a lack of evidence on discriminative validity (Blank et al., 2012); however, criterion, content and face validity are supported (Henderson et al., 2007). The dependent variable – sensory processing and integration – was measured by SPM, a parent questionnaire. Reliability and validity of the SPM is good (Parham et al., 2007). There is also an additional subsection of planning and ideation. Norm-referenced standard scores are available for eight subsections: social participation, vision, hearing, touch, body awareness, balance and motion, planning, and ideation. Also available is the total score, which combines all sections plus taste and smell (but not social participation).

For the purpose of this study, the Home Form, completed by a parent, was used. The SPM was standardised on 1051 elementary school-aged children, their ages ranging from five to 12 years. Internal consistency and test-retest reliability data are reported as 0.77 to 0.95 and 0.94 to 0.98 respectively (Parham et al., 2007). SPM *t*-scores were used for analysis to assist hypothesis testing. A *t*-score in the range of 60 to 69 (some problems) indicates mild to moderate difficulties in behavioural or sensory

functioning and equate to between +1 and +2 SD. A score of 70 or above (a definite difference) indicates a significant sensory processing and integration problem that may have a noticeable effect on the child's daily functioning and equate to +2 SD above norm.

Sample and statistical analysis

This section will discuss reducing bias and outline the statistical tests selected.

Potential sources of bias can occur at planning, implementation or analysis stage. In this study, selection of subjects was based on time sampling. While random selection may be preferable, the calculation of sample size reduces the effect of bias. The risk of examiner bias exists at the level of the assessing therapist and the data collector. The retrospective study design means data was collated from case notes of children assessed by their treating occupational therapist, who was blind to the study criteria. Standard scores for MABC-2 and *t*-scores for the SPM were used. To reduce study data collector bias, all data were classified through standardised test scores or preset categories.

Analysis was undertaken using the Statistical Package for Social Sciences (SPSS) version 20 workbook. To test the first question (Do children with DCD have reported sensory processing difficulties?), a one-sample *t*-test was selected to compare SPM scores to the typical population. The test value was 50, $t = 21.2$ (92 d.f.), $p < 0.001$. To test question 2 (Is there an association between reported sensory processing difficulties and DCD?), Spearman's bivariate correlation was used to explore the extent of any monotonic relationship between all SPM scores (total and subsections) with MABC-2 total and subsection scores. Spearman's rather than Pearson's correlation was used because the scores cannot be assumed to have the equal value interval property. To test question 3 (Is sensory processing the same in children with and without co-occurring conditions?), robust *t*-tests were used to compare group means of SPM *t*-scores, total scores and seven subsection scores. A *t*-test with bootstrap, with 1000 replications, allowed for possible non-compliance with distributional assumptions such as non-normality and non-homogeneity of variance.

Results

Participant profile

A review of case notes identified 159 sets of data. Sixty-six sets of notes recorded incomplete data, giving a total of 93 complete notes (60%), at the level required by power calculation. All notes were analysed. Table 1 outlines demographic data. Of the reported functional concerns, 15% were reported at home only and 85% both at home and at school. Primary recorded areas of concern were self-care and handwriting. Exploring neurodevelopmental co-morbidity at the time of the study, 46% of children had a diagnosis of ASD and 1% of ADHD; 53% had no diagnosis other than DCD. All total standard scores on the MABC-2 were at or below 6, with a mean score of 4.39.

DCD and sensory processing and integration difficulties

The sample mean SPM total score was 66 with a range of 40 to 79 (standard deviation 7.45). This compared to a typical mean of 50. Taken together, this gives a Cohen's *d* (Cohen, 1988) large effect size of $(66 - 50)/7.45 = 2.14$.

Incidence may be calculated by identifying the number of cases of sensory processing difficulties within the number of cases identified with DCD, within a time period. Incidence of sensory processing difficulties falling into the definite difference range was 32%. A further 56% scored in the 'some problems' range. Most children presenting with DCD (88%) also present with some or definite differences in sensory processing, as reported by parents, through the SPM. 12% showed no evidence of sensory processing difficulties as reported by parents. Using a *t*-test, *t*-value was 21.46 and significance $p < 0.001$. In response to question 1, most children with DCD have reported sensory processing difficulties.

Motor skills and sensory processing and integration

Motor skills, as measured by MABC-2 and parent-reported sensory processing, were compared. Spearman's rho correlation demonstrated no relationship, as

Table 1. Participant demographics ($n = 93$).

Age (years)	5-6	7-8	9-10	11-12	Total <i>n</i> (5)	Mean age
Male (<i>n</i>)	20	40	14	3	77 (83)	8y 0m
Female (<i>n</i>)	3	9	3	1	16 (17)	8y 4m
Total (<i>n</i>)	23	49	17	4	93 (100)	8y 1m
Selected measures						
MABC-2 Total standard score Mean (SD)	4.26 (1.51)	4.19 (1.51)	4.8 (1.01)	5.75 (0.5)	4.39 (1.47)	
SPM Total <i>t</i> -score	65.91 (7.94)	66.00 (8.09)	69.35 (7.23)	63 (6.78)	66.47 (7.87)	

MABC-2: Movement Assessment Battery for Children; SPM: Sensory Processing Measure

illustrated in Table 2. Findings were consistent across subsections (a range of $p = 0.122$ to $p = 0.984$), with the exception of MABC-2: aiming and catching and SPM: hearing, which approached significance ($p = 0.053$), and MABC-2 total score and social participation ($p = 0.035$). A significant positive relationship was observed between social participation with all aspects of sensory processing and total motor skills. In response to question 2, there was no apparent correlation between the severity of motor impairment and the severity of reported sensory processing difficulties.

Sensory processing and integration in DCD and co-occurring conditions

The number of children with co-morbid ADHD ($n = 1$) was insufficient for analysis.

Numbers recruited with co-morbidity allowed comparison of data between those with DCD only and those with DCD plus ASD, as illustrated in Table 3. Age and male:female distribution was similar across groups but mean scores differed, although both group means fell within the 'some problems' range.

For total scores, of those children with DCD and ASD, 49% scored within the definite difference range. For those with DCD only, 18% fell within the definite difference range. In all sections, 39–49% of those with DCD and ASD fell within the definite difference range. In those with DCD only, unsurprisingly, body awareness, balance, and planning and ideation demonstrated high levels of children with definite difference (24–33%). Definite difference in touch and hearing in the DCD only group was higher than expected at 16% and 22% respectively. Levels of definite difference in social participation and vision were lower at 5% and 4% respectively. All mean

scores of both groups fell within the 'some problems' range (+1 to +2 SD), except the DCD only group for touch and vision, which fell within the typical range (below +1 SD).

To explore the differences between those with and without additional ASD, the t -test with 2-tailed significance was used (Table 4). Total score, vision, hearing and touch demonstrated a high level of differences, with p -values at or below 0.002. Body awareness, balance and motion, planning and ideation did not demonstrate a difference between those with and without additional ASD. In response to question 3, there was difference in reported sensory processing for DCD only against DCD plus ASD.

Discussion and implications

This study identified levels of sensory processing and integration difficulties in a clinical population of children with coordination difficulties. While many families with a child with DCD reported definite or at least some

Table 3. Demographics of group split by co-occurring condition.

	n (%)		Mean age (SD)
DCD only	Male	41 (80)	8y (1y 6m)
	Female	10 (20)	
	Total	51	
DCD and ASD	Male	36 (86)	8y (1y 6m)
	Female	6 (14)	
	Total	42	

DCD: developmental coordination disorder; ASD: autistic spectrum disorder

Table 2. Spearman's rho correlation Sensory Processing Measure with Movement Assessment Battery for Children - 2.

SPM		Total	Social participation	Vision	Hearing	Touch	Body awareness	Balance and motion	Planning and ideation
MABC-2 total	Correlation coefficient	-0.042	.217*	-0.015	0.066	0.060	-0.153	-0.106	-0.004
	significance (2-tailed)	.690	.035	.884	.530	.565	.142	.308	.972
MABC-2 manual dexterity	Correlation coefficient	-0.061	0.123	0.086	0.037	-0.069	-0.158	-0.087	-0.069
	significance (2-tailed)	.561	.239	.408	.720	.506	.129	.405	.507
MABC-2 aiming and catching	Correlation coefficient	0.179	0.173	0.091	0.201	0.118	0.108	0.032	0.066
	significance (2-tailed)	.085	.096	.384	.053	.256	.302	.762	.525
MABC-2 total	Correlation coefficient	-0.002	0.161	-0.036	-0.026	0.130	-0.059	-0.045	0.056
	significance (2-tailed)	.984	.122	.730	.805	.210	.573	.668	.593

MABC-2: Movement Assessment Battery for Children; SPM: Sensory Processing Measure

*Correlation is significant at the 0.05 level (2-tailed).

Table 4. Results of *t*-test and descriptive statistics of children with DCD only against DCD plus ASD.

	SPM						95% CI for Mean Difference	<i>t</i>	d.f.
	DCD only			DCD plus ASD					
	<i>M</i>	<i>SD</i>	<i>n</i>	<i>M</i>	<i>SD</i>	<i>n</i>			
SPM total	64.41	7.811	51	68.90	6.297	42	(1.699, 7.305)	3.288***	91
SPM social participation	60.43	7.880	51	67.62	5.772	42	(4.454, 10.125)	4.995***	91
SPM vision	59.27	8.333	51	66.69	6.919	42	(4.371, 10.262)	4.902***	91
SPM hearing	60.18	10.176	51	67.93	8.532	42	(3.686, 11.538)	4.061**	91
SPM touch	56.61	13.000	51	66.93	7.243	42	(6.575, 14.576)	4.894***	91
SPM body awareness	64.25	10.371	51	64.17	8.115	42	(-3.728, 3.849)	-0.046	91
SPM balance and motion	66.62	8.829	51	63.75	10.851	42	(-0.949, 6.962)	1.420	91
SPM planning and ideation	65.41	8.766	51	65.98	7.199	42	(-2.782, 3.650)	0.350	91

DCD: developmental coordination disorder; ASD: autistic spectrum disorder

SPM: Sensory Processing Measure;

Note: *t*-test with bootstrap

***p* < 0.01

****p* < 0.001

differences in sensory processing and integration, a number did not report any differences in sensory processing and integration on the SPM. Therefore, the coexistence of sensory processing and integration difficulties and DCD cannot be assumed using the current evidence. Where sensory processing and integration difficulties are present, they have an impact on participation in daily life and function, and these difficulties should be considered in both the assessment and the planning of interventions for children with DCD. However, it is important to remember that many factors can contribute to participation challenges, including performance skills, occupation, and the social and physical environment of the individual.

The data set explored in this study identified a significant relationship between social participation and both sensory processing and integration difficulties and total motor skills. It is important to note that participation challenges may or may not be related to sensory processing and integration. Cosby et al. (2010) looked in more detail at social participation in children with sensory processing and integration disorder. When compared with typically developing children, the sensory processing and integration disorder group showed less participation in diverse social networks. They also experienced less engagement with team sports than typically developing children and less enjoyment in activities with clear expectations and social rules. They did, however, report more enjoyment of skill-based and recreational activities than typically developing children. Jarus et al. (2011) looked at participation patterns of school-aged children with DCD and found a reduced variety of participation and increased 'socially alone' activities. Cosby et al. (2010) suggest that to promote positive social interaction, social activities should be planned around areas of strength. In this study, both DCD and sensory processing and integration difficulties appeared to demonstrate a relationship with social participation. This finding is not new but does underline the importance of considering the child's social participation in clinical practice.

The challenge for clinicians working with children with DCD should not be 'how do I change motor skills?' but 'how do I support increased participation for this child?' Task-specific and cognitive approaches provide evidence-based tools for practitioners and address the goals of many service users and their families. However, as recognised by Zwicker et al. (2012), no single approach has been fully substantiated by research and none has been grounded in neurobiological data. The question in terms of child- and family-centred intervention is not 'what works?' but 'what works for whom?'

In this study, on a functional level, all DCD children faced challenges in the home environment (such as self-care), and most also faced challenges in the school environment (for example, handwriting). Lane (2012) reminds us that we can change the physical world or what takes place in the physical world through adaptation or strategy. Moreover, it is possible that by reframing movement, emotional concerns and behavioural concerns in the context of sensory processing and integration difficulties, adults supporting the child may alter their beliefs and attitudes, thus lowering barriers and increasing the child's opportunities for participation. A greater understanding of self empowers active choice and informs the need for active participation. Reframing movement and behaviour concerns in the context of sensory processing and integration difficulties provides the opportunity for adaptation within the environment and equips carers with resources to influence the child's future development.

Past research suggests that growth, development and behaviour can be enhanced by enriching the sensory environment, contextualised through meaningful activity (Lane and Schaaf, 2010). Ayres Sensory Integration Therapy (ASI) (Parham et al., 2011) is a fidelity-based intervention which may provide the opportunity to develop strategies supported by neural change (Lane and Schaaf, 2010). Evidence of the effectiveness of ASI (where fidelity is demonstrated) for children with ASD is described as 'moderate'. Studies that appraise sensory strategies and

sensory-based intervention that do not demonstrate fidelity are described as 'less effective' (Watling and Hauer, 2015). It is suggested that further research is warranted to explore whether occupational therapists should give more consideration to the sensory processing and integration difficulties and their impact on function in children with DCD. It is beyond the remit of this study to explore what is the most effective means of intervention for various client groups.

This study found no correlation between sensory processing and integration as measured by the SPM and motor coordination as measured by MABC-2. This outcome does not support the findings of White et al. (2007). In White's study, a relationship was found between sensory sensitivities and the fine motor skills used in self-care. The motor tool used in the current study (MABC-2) looks at speed and dexterity of hand movement in peg-board, drawing and bead-threading tasks but does not link fine motor skills to self-care. The SPM considers sensory systems but does not identify the type of dysfunction within each sensory system, such as over- or under-responsiveness. Therefore, it is difficult to directly compare White's findings to the findings of this study. The outcome of this study may reflect limitations in the tools selected.

This study establishes the presence of sensory processing and integration difficulties in a group of children with DCD. It is beyond the remit of this paper to explore whether or not sensory processing and integration difficulties are reflective of a co-occurring condition or are a feature of DCD. However, children with identified co-morbid ASD presented different profiles on the SPM to those with only DCD. High levels of poor body awareness, balance and motion, along with planning and ideation concerns, were identified by the SPM for all children. Rates of difficulty in the areas of vision, hearing and touch were much higher in those with additional ASD, and sensory sensitivity to sound is often noted in the ASD population. It was unexpected to find high rates of reported sound processing difficulties in those with DCD only. Twenty-two percent of those with DCD only fell into the definite difference range for response to sound; in a typical population this figure would be less than 2%. This led to further exploration of the literature of a potential link between processing sound and motor skills. Rigoli et al.'s (2012) work on executive function suggested a relationship between ball skills and academic achievement (specifically word-reading and numerical operations) through verbal and visuospatial working memory. Rigoli et al. (2012) suggest that ball skills reflect complex motor planning and may rely on the same neural mechanism involving the lateral cerebellum as verbal working memory. Although conclusions cannot be drawn from the data presented, the high rate of hearing difficulties reported on the SPM hearing subsection for children with no co-morbid ASD is noteworthy. The interaction between perception, executive function and action of children with DCD may benefit from further investigation.

Definite differences in the areas of vision, hearing and touch were lower in the DCD only group versus the DCD

plus ASD group. However, most mean scores remained in the 'some difficulty' range (+1 to +2 SD above mean) (Table 1). Between 43% and 59% of the children with DCD and no co-existing condition were reported to have definite or some difficulties in the areas of vision, hearing and touch. With an approach to intervention that is only task-specific, it is unlikely that these underlying difficulties, and the potential challenges they present to child and family participation, would be taken into account. Therefore, we should consider addressing sensory processing and integration in children with DCD in our clinical practice.

Occupational therapy firmly advocates for participation, and Bagby et al.'s (2012) research provides some insight into how sensory experiences impact on the participation opportunities for families of children with DCD. By understanding the contribution of sensory processing and integration to participation, occupational therapists are better equipped to provide contextually relevant problem-solving to support children and their families. An alternative cognitive-based approach to supporting change in family life has been identified by Graham and Rodger (2010) in their work with parents on occupational performance coaching. Preliminary research data (Dunn et al., 2012) suggests that for children with ASD, both child participation and parental competence are improved by contextual parent coaching that includes the exploration of sensory patterns. Cognitive approaches to changing participation in children with sensory processing and integration difficulties merit further consideration.

This paper provides a step in our understanding of the co-occurrence of DCD and sensory processing and integration difficulties. It may support further exploration of the relationship between motor skills, sensory processing and integration and the impact on function and participation. If a relationship is found, there is an argument for investigating the impact of changing sensory processing and integration on occupational performance. There is evidence (Blank et al., 2012) that intervention should be offered to all children with DCD, as this yields better results than no intervention. Beyond this, there is limited data to help professionals identify the best strategies to help specific children. More research is needed to identify the type and dosage of intervention that would support the best occupational outcome for children and their families.

The SPM is a robust and reliable assessment tool; however, no normative data has been collected on a European population. Our findings are based on a North American population and may or may not reflect the United Kingdom experience. Collation of UK and European normative data is desirable and would support future research and practice.

The sample for this study was collected by time frame and was not a random selection of cases. It reflects a clinical population, but may have differed from a random sample. The ratio of boys to girls differed from other studies, at 4.9:1 in this study and 1.9:1 in a recent UK population-based study (Lingam et al., 2009). This may indicate an under-representation of girls. Data does not

indicate the number of referrals that resulted in a DCD diagnosis. Such data might provide greater insight into whether girls are accessing services appropriately.

Data collection was completed at the point of access to occupational therapy services, and some children in the cohort will have gone on to further assessment (for example, with orthoptists or child and adolescent mental health teams). No data were collected on potential co-morbid anxiety or attention, both of which have been associated with DCD.

This data reflects the assessment of function at a single point in time. In addition, more than 40% of data sets within the time frame had incomplete data. The reasons for this were not investigated and may have influenced results. However, statistical sample size was calculated and met, reducing potential bias error. Although basic data were collected on functional concerns, no detailed data were collected on function and participation (for example, Participation and Environment Measure for Children and Youth (PEM-CY) (Coster et al., 2010)). Collecting such data would be a logical next step in identifying the contribution of sensory processing and integration difficulties to participation challenges faced by children with DCD and their families.

It cannot be assumed that DCD equates to sensory processing and integration difficulties. No relationship was observed between motor skills and sensory processing and integration as measured by the tools in this study. Assessment of the individual is indicated with consideration of both functional and performance skills. It is recommended that sensory processing and integration should be considered where there are indicators that it may be impeding participation. A one-size-fits-all approach to intervention may not provide the optimum approach to service delivery in terms of either cost or outcome.

Conclusion

Parent reports indicate that 32% of a clinical population of children with DCD present with definite sensory processing and integration difficulties, as identified by the SPM. A further 56% of parents identified some difficulty. This study showed no apparent correlation between motor skills and reported sensory processing and integration difficulties. When comparing children with only DCD and those with co-occurring ASD, body awareness, balance and motion, and planning and ideation showed similar levels of challenge, while vision, hearing and touch demonstrated a greater reported challenge in those with additional ASD. Sensory processing and integration difficulties are known to impact on function and participation; therefore, sensory processing and integration should be considered as a possible barrier to participation in children with DCD.

Key findings

- Most children with DCD have some difficulty with sensory processing and integration, as reported by parents.

- The type of sensory processing and integration difficulties appears to vary between those with and without co-occurring ASD.

What the study has added

Large numbers of children attending occupational therapy and presenting with DCD have sensory processing and integration difficulties. Sensory processing and integration difficulties and their impact on participation should be considered when assessing children with DCD.

Acknowledgements

We would like to acknowledge Moyra Pugh (Occupational Therapy), Edith Hawkins (Research and Development) and the Dingley Occupational Therapy team at Royal Berkshire Hospital for facilitating this project. The Occupational Therapy and Research teams, School of Health Sciences, University of Ulster and Sensory Integration Network Research Committee for guidance. David Boniface, Chartered Statistician, Health Behaviour Research Center, University College London for additional statistical support. Vittoria D'Alessio for help with editing.

Research ethics

Ethical approval was obtained in 2013 from the National Research (REC#13/WM/0252), University of Ulster and Royal Berkshire Hospital Trusts' Ethics Committees. Data collection was retrospective and anonymised; individual written consent was not required by the ethical committees.

Declaration of conflicting interests

The authors confirm there is no conflict of interest.

Funding

This research was funded by Sensory Integration Network Research Grant SIN-MS-2012.

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