THE JOURNAL OF CHILD PSYCHOLOGY AND PSYCHIATRY

ACAMH THE ASSOCIATION FOR CHILD AND ADOLESCENT MENTAL HEALTH

Journal of Child Psychology and Psychiatry 55:3 (2014), pp 237–246 doi:10.1111/jcpp.12139

Comorbidities in preschool children at family risk of dyslexia

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Background: Comorbidity among developmental disorders such as dyslexia, language impairment, attention deficit/hyperactivity disorder and developmental coordination disorder is common. This study explores comorbid weaknesses in preschool children at family risk of dyslexia with and without language impairment and considers the role that comorbidity plays in determining children's outcomes. **Method:** The preschool attention, executive function and motor skills of 112 children at family risk for dyslexia, 29 of whom also met criteria for language impairment, were assessed at ages 3½ and 4½ years. The performance of these children was compared to the performance of children with language impairment and typically developing controls. **Results:** Weaknesses in attention, executive function and motor skills were associated with language impairment rather than family risk status. Individual differences in language and executive function are strongly related during the preschool period, and preschool motor skills predicted unique variance (4%) in early reading skills over and above children's language ability. **Conclusion:** Comorbidity between developmental disorders can be observed in the preschool years: children with language impairment have significant and persistent weaknesses in motor skills and executive function compared to those without language impairment. Children's early language and motor skills are predictors of children's later reading skills. **Keywords:** Comorbidity, language disorder, dyslexia, motor skills, executive function.

Introduction

In recent years, there has been growing interest in the frequent co-occurrence of developmental disorders; indeed, it is now well recognised that pure disorders are rare in development and that 'co-morbidity' is common (Hulme & Snowling, 2009; Williams & Lind, 2013).

Evidence suggests that about 40% of school-aged children with one neurodevelopmental disorder (e.g. dyslexia, language impairment, attention deficit/hyperactivity disorder (ADHD) and developmental coordination disorder (DCD)) will also meet diagnostic criteria for another neurodevelopmental disorder (e.g. Kadesjö & Gillberg, 1999; McArthur, Hogben, Edwards, Heath & Mengler, 2000; Rochelle & Talcott, 2006; Willcutt & Pennington, 2000). These findings suggest that aetiological factors that adversely influence brain development can have diverse effects (Pennington, 2006). However, less is known about comorbidity between neurodevelopmental disorders during the preschool years when the foundation for later learning is established.

It is well recognised that children with preschool language impairment are at high risk of developing reading difficulties (Bishop & Snowling, 2004) and that children at family risk of dyslexia who go on to have significant reading difficulties are likely to have a history of oral language difficulties (e.g. Scarborough, 1990; Snowling, Gallagher & Frith, 2003).

Attention deficits might also be expected to increase the risk of learning disorders by compromising the acquisition of key academic skills, including behaviour regulation (Barkley, 1997). Indeed, preschool attention problems have been found to predict later reading achievement (Rabiner, Coie & Conduct Problems Prevention Research Group, 2000) which may reflect the operation of shared genetic risk factors influencing the development of both reading and attentional difficulties (e.g. McGrath et al., 2010; Willcutt et al., 2007).

Impairments in motor skills are also frequent in children with dyslexia (Kaplan, Wilson, Dewey & Crawford, 1998), although the evidence for an association between motor difficulties and specific reading difficulties in the school years is not strong (Rochelle, Witton & Talcott, 2008). The occurrence of motor deficits in children with language impairment, on the other hand, is well documented (Hill, 2001) and Bishop (2002) found shared genetic liability for impairments on speeded motor tasks and tasks requiring speech production, suggesting that the genes that put a child at risk of speech/language difficulties may also affect motor development.

In summary, evidence for comorbidities between neurodevelopmental disorders is strong but a limitation of current evidence is a lack of longitudinal studies. We would argue that understanding how symptoms and cognitive markers of different disorders co-occur in the preschool years is critical to the development of causal models of learning disorders as it will enable us to understand how comorbidities affect children's learning. In this regard, a recent study by Aro, Eklund, Nurmi and Poikkeus (2012) showed that children at family risk of dyslexia are at increased risk of poor social outcomes if they

Conflicts of interest statement: No conflicts declared.

have weak language skills *and* poor behavioural regulation in the preschool years, ascertained by parental report. In addition, Viholainen et al. (2006) found that some children at family risk of dyslexia were slower to reach developmental motor milestones in the first 2 years of life. These children also experienced early language difficulties (they had smaller vocabularies and poorer inflectional skills) at age 3 and turned out to be slower readers at age 7.

Pennington's (2006) multiple deficit model suggests that a child's developmental outcome will reflect a complex interplay between multiple risk factors and Hudziak, Achenbach, Althoff and Pine (2007) posit that the manifestation of any given developmental psychopathology will be determined by multiple sources of variance including the degree to which symptoms of comorbid disorders are present. Studying children at family risk of dyslexia gives us the opportunity to investigate cognitive precursors of dyslexia and search for these potential risk markers (endophenotypes).

In this study, we report data from the first two phases of a longitudinal study comparing preschool children who are at family risk of dyslexia with and without language impairment to those who have language impairment only and TD controls. This design enables us to consider whether two different risk factors for literacy difficulties (familial genetic risk or early language impairment) are differentially associated with comorbid weaknesses in motor skills or executive function (and thus an increased risk of comorbid disorders such as DCD or ADHD). Given that previous studies have shown that only about 50% of children at family risk for dyslexia will go on to have literacy difficulties (Scarborough, 1990; Snowling et al., 2003), this study is also novel in considering the broader cognitive strengths and weaknesses of children at family risk of dyslexia prior to reading instruction and thus enables us to explore the developmental progression of comorbidities while avoiding the confound of reading failure.

Our primary research question was: Are children at family risk of dyslexia at increased risk for motor difficulties and/or impairments in executive function during the preschool period? Second, we asked whether these impairments were associated with preschool language difficulties that were prevalent in the family risk group. Finally, we wanted to explore whether markers of comorbid disorders (specifically markers of DCD or ADHD as measured by objective measures of motor skills and executive function) could help predict which children maybe most at risk of later reading difficulties.

Method

Data are from the first two phases of the Wellcome Language and Reading project; children were aged 3–4 years at T1 and 4–5 years at T2 approximately 11 months later.

Participants

Families with 3-year-old children were recruited to the study via advertisements placed in local newspapers, nurseries and webpages of support agencies for individuals with dyslexia/language difficulties, and via speech and language therapy services in Yorkshire, UK. None of the 242 children recruited to the study met our exclusionary criteria (MZ twinning, chronic illness, deafness, English as a second language, care provision by local authority and known neurological disorder such as cerebral palsy, epilepsy, ASD). Ethical clearance for the study was granted by the University of York, Department of Psychology's Ethics Committee and the NHS Research Ethics Committee. Parents provided informed consent for their child to participate. Following recruitment the children were classified into groups using a two-stage process: first, to determine whether or not they were at family risk for dyslexia and second, to determine whether or not they had current language impairment. This 2 (family risk yes/no) × 2 (language impairment yes/no) design yielded four groups: family risk only (FR), language impaired only (LI), family risk and language impaired (FRLI) and typically developing (TD).

Family risk. Previous family risk studies have used either self-report or objective measures to determine risk status. In this study, we obtained self-report (Adult Reading Questionnaire; Snowling, Dawes, Nash & Hulme, 2012) and objectively measured the literacy skills of parents who consented to be assessed. Children were classified as family risk if (a) a parent self-reported as dyslexic, (b) a parent scored below 90 on a literacy composite of nonword reading and spelling (see Snowling et al., 2012 for details), (c) a parent had a discrepancy between nonverbal ability and the literacy composite of 1.5 standard deviations, with a literacy composite standard score of 96 or below, or (d) a sibling had a diagnosis of dyslexia from an educational psychologist or a specialist teacher. According to these criteria, 120/242 children were classified as being at family risk for dyslexia.

Language impairment. language impairment status was determined at T1 using three subtests, basic concepts, expressive vocabulary and sentence structure, from the Clinical Evaluation of Language Fundamentals (CELF) – Preschool 2 UK (Semel, Wiig & Secord, 2006) and the screener from the Test of Early Grammatical Impairment (TEGI; Rice & Wexler, 2001) comprising the third person singular/s/and past tense probes. These tests assess receptive and expressive skills across multiple domains of language (vocabulary, syntax and grammatical inflection) (Tomblin et al., 1997). Children were classified as language impaired if they 'failed' 2/4 language

tests (a fail being a score of 85 or below on the CELF subtests or failure of the TEGI screener)[1]

Based on our research criteria, 35/120 children at family risk of dyslexia were classified as having language impairment as were 31/46 children referred for speech/language difficulties. Children who were referred to the study because of speech/language concerns but who did not meet our criteria for language impairment were excluded from further analyses ($N = 15$).

Typically developing group. Of the 76 children initially referred as typically developing, five met criteria for language impairment. These children were considered to be language impaired for the purpose of the study. The remaining 71 children, who were not at family risk of dyslexia, whose parents did not raise concerns about their speech/language development and who did not meet our criteria for language impairment, formed our typically developing group.

There was a small amount of attrition between T1 and T2 therefore data from two typically developing children, two children at family risk of dyslexia, four children with language impairment and six children at family risk of dyslexia who also had language impairment are not included here.

Sample characteristics. Table S1 (see Appendix S1) includes information about the age, gender, SES status, nonverbal IQ (NVIQ) and language ability of the four groups (TD: $N = 69$, FR: $N = 83$, LI: $N = 32$ and FRLI: $N = 29$). The groups did not differ in age, but there were group differences in SES status and NVIQ. On average, the typically developing children were from higher SES backgrounds than children with language impairment (LI, FRLI) and they performed significantly better on the NVIQ tasks than children in the family risk group, who in turn performed better than the children with language impairment. There were relatively more boys than girls classified as language impaired, but this difference was not statistically significant. As expected given the diagnostic criteria the children with language impairment (LI, FRLI) performed worse than the typically developing and family risk groups on the language measures (CELF Basic Concepts, CELF Expressive Vocabulary, CELF Sentence Structure and TEGI screener; see Nash, Hulme, Gooch and Snowling (2013) for further information regarding the speech and language profiles of the groups).

Tests and procedures

Alongside diagnostic language tests and NVIQ assessment, each child completed measures of motor skills and executive function (see Appendix S2). Parents also completed questionnaires about their child's attention, behaviour and motor coordination skills.

Tests were administered in a single 1.5-hour session at T1 and across two 1-hour sessions at T2. The sessions were conducted in the child's home and breaks were provided as appropriate.

Motor skills. Children completed three subtests from the Movement Assessment Battery for Children-2 (Henderson, Sugden & Barnett, 2007); posting coins, bead threading and bicycle trails to assess fine motor skills (T1, T2).

As part of a structured family interview, parents were asked to report the age at which their child started walking and at T2 parents completed the Developmental Coordination Questionnaire (DCDQ'07; Wilson et al., 2009), a screening tool to assist in the identification of developmental coordination difficulties.

Executive function. Each child completed a Visual Search task (Apples Task; Breckenridge, 2008) to measure selective attention (T1, T2), a computerised Auditory Continuous Performance Test (ACPT) (e.g. Kerns & Rondeau, 1998; Mahone, Pillion & Hiemenz, 2001) to assess sustained attention (T2), the Dog–Bird Go/No-Go task (a version of the Bear–Dragon Go/No-Go task; Reed, Pien & Rothbart, 1984) (T1) and the Head, Toes, Knees and Shoulders (HTKS) task (Burrage et al., 2008; T1, T2) to assess behavioural inhibition/self-regulation plus Block Recall from the Working Memory Test Battery for Children (Pickering & Gathercole, 2001) to measure visuospatial memory (T2).

At T2 parents completed the Strengths and Weaknesses of ADHD symptoms and Normal behaviour Questionnaire (SWAN; Swanson et al., 2006), a dimensional scale that captures variations in ADHD symptoms related to strengths as well as weaknesses in attention/behaviour (Polderman et al., 2007).

Early literacy. Early literacy skills were also assessed at T2 with the letter sound knowledge and early word reading tasks from the York Assessment of Reading for Comprehension (YARC; Hulme et al., 2009) and a letter writing task (children had to write 10 letters). Data from the four groups on the measures of early literacy are presented in Table S1.

Data analysis

We had multiple measures of language, early literacy, motor skills and executive function, hence we conducted confirmatory factor analysis on measures administered at T1 (Figure 1) and T2 (Figure 2; analyses were conducted Stata 12.0 using the MLMV estimator to deal with missing values). Subsequently, motor and executive function factor scores from these CFAs were analysed in 2×2, Family Risk (±) × Language Impairment (±), ANOVAs. Interactions in these ANOVAs can be taken as evidence for the nonindependence of the two factors (family risk and language impairment).

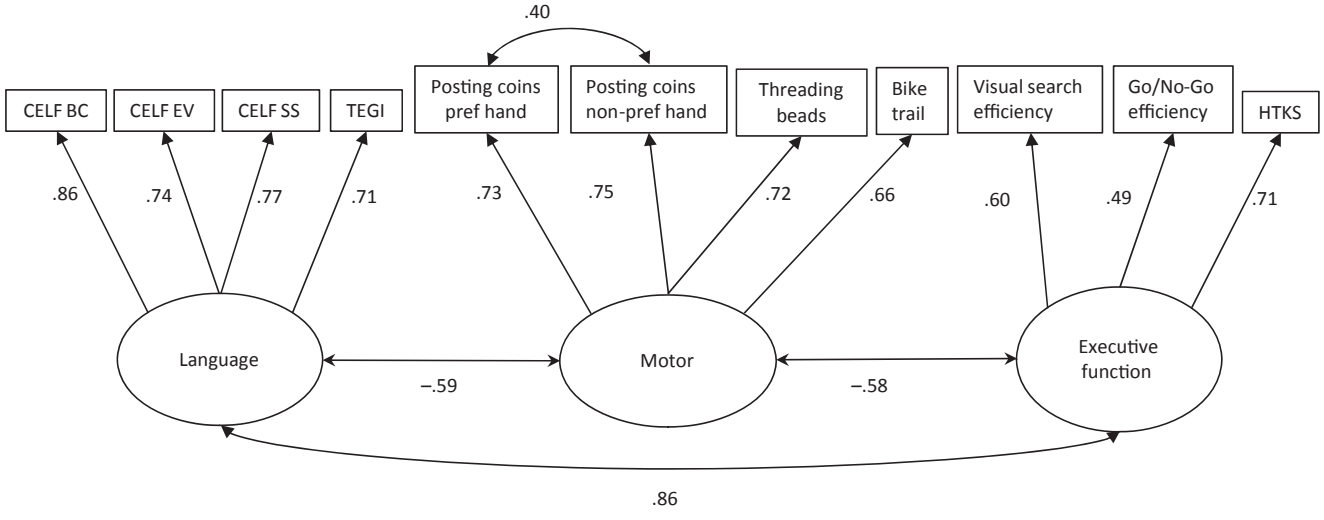

Figure 1 Confirmatory factor analysis of the T1 language, motor and executive function variables. $Chi^2(40) = 59.891$, $p = .022$; RMSEA = .048; CFI = 0.974; TLI = 0.964

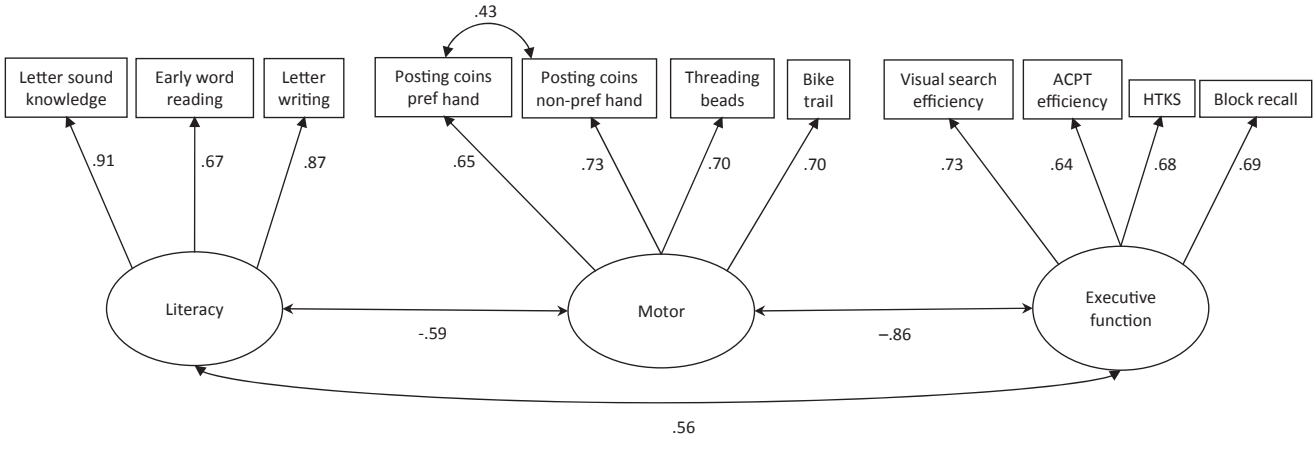

Figure 2 Confirmatory factor analysis of T2 literacy, motor and executive function variables. $Chi^2(40) = 70.881$, $p = .002$; RMSEA = .060; CFI = 0.969; TLI = 0.957

Results

Tables 1 and 2 show means and standard deviations for the four groups on the individual motor skills and executive function measures administered at T1 and T2 together with the motor and executive function factor scores for each group derived from the confirmatory factor analyses presented in Figures 1 and 2. The tables also display results from the ANOVAs along with η_p^2 as a measure of effect size and Games Howell post hoc comparisons.

Motor skills

At both T1 and T2, children with language impairment (LI, FRLI) performed more poorly than children without language impairment (TD, FR) on the individual motor tasks and the motor factor score (note high scores on the raw measures indicate poor performance and hence low factor scores reflect good performance). The significant Language Impairment × Family Risk interaction on the T1 and T2 motor factor scores show that the effect of language impairment was significantly greater for children not at family risk of dyslexia (with post hoc comparisons revealing TD < FR < LI = FRLI). The correlation between T1 and T2 motor factor scores was strong ($r = .79$, $p < .01$) indicating that this factor has good longitudinal stability.

Parental report data support our findings from objective measures; children with language impairment were reported to have started walking later than children without language impairment. On the DCDQ children with language impairment were rated as having significantly weaker fine motor and general coordination skills compared to children without language impairment. The only exception to the general pattern was that for rated dynamic

Table 1 Means and standard deviations for the four groups on the T1 and T2 motor skills measures. Main effects and interactions from the 2 × 2 ANOVA are also displayed

	TD			FR			LI			FRLI			Main effect				Interaction	
													FR		LI		FR × LI	
Measures	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*F*	ηp2	*F*	ηp2	*F*	ηp2
T1 Tasks																		
Posting coins pref (sec)	69	27.77_{a}	5.24	83	30.86_{b}	8.46	31	46.26_{c}	29.83	29	34.48_{bc}	10.56	4.48*	0.02	29.05**	0.12	13.12**	0.06
Posting coins nonpref (sec)	69	32.23_{a}	8.04	81	35.23_{ab}	9.37	24	47.75_{c}	19.65	29	39.45_{bc}	12.47	2.2	0.01	30.52**	0.13	10.02**	0.05
Threading beads (sec)	69	55.84_{a}	17.98	81	63.41_{ab}	32.96	28	84.21_{b}	44.19	27	68.56_{ab}	28.32	0.72	0.00	12.43**	0.06	5.97*	0.03
Bicycle trail errors	66	7.68_{a}	3.99	81	8.91_{ab}	3.94	29	12.17_{c}	5.84	27	11.15_{bc}	5.35	0.02	0.00	22.85**	0.10	2.57	0.01
T1 motor factor score	69	-0.45_{a}	0.43	83	-0.14_{b}	0.71	32	0.98_{c}	1.32	29	0.38_{c}	0.67	1.53	0.01	71.20**	0.25	15.36**	0.07
T2 Tasks																		
Posting coins pref (sec)	69	23.14_{a}	3.60	83	24.51_{a}	8.69	31	30.59_{b}	10.52	28	26.29_{ab}	6.19	1.67	0.01	16.41**	0.07	6.19*	0.03
Posting coins nonpref (sec)	69	26.70_{a}	4.97	83	27.72_{ab}	7.08	31	35.61_{b}	16.36	29	29.86_{ab}	6.85	3.29	0.02	18.00**	0.08	6.77*	0.03
Threading beads (sec)	68	36.13_{a}	10.02	83	41.49_{ab}	24.31	31	54.35_{b}	24.35	29	42.83_{ab}	16.59	1.04	0.01	10.49**	0.05	7.83**	0.04
Bicycle trail errors	69	3.72_{a}	3.31	83	5.05_{ab}	4.52	30	7.13_{b}	4.88	29	6.28_{b}	3.83	0.14	0.00	13.40**	0.06	2.97	0.01
T2 motor factor score	69	-0.41_{a}	0.45	83	-0.09_{b}	0.91	32	0.81_{c}	1.20	29	0.35_{c}	0.70	0.29	0.00	44.51**	0.18	9.71**	0.04
Age of walking (months)	69	13.45_{ab}	2.37	81	12.56_{a}	2.33	32	14.58_{b}	3.24	29	13.41_{ab}	3.38	6.43*	0.03	6.00*	0.03	0.12	0.00
T2 DCDQ																		
Dynamic motor control (/30)	62	21.87_{a}	4.33	76	22.34_{a}	4.17	28	19.25_{a}	6.02	24	22.29_{a}	4.93	5.40*	0.03	3.12	0.02	2.89	0.02
Fine motor (/20)	60	15.55_{a}	3.60	76	14.95_{a}	3.67	28	11.18_{b}	5.05	25	13.44_{ab}	4.01	1.69	0.01	21.28**	0.10	5.05*	0.03
General coordination (/25)	62	20.06_{a}	3.81	77	19.58_{ab}	3.91	29	17.14_{b}	4.70	25	17.80_{ab}	4.85	0.02	0.00	12.53**	0.06	0.74	0.00
Total (/75)	60	57.50_{a}	9.33	75	57.04_{a}	9.05	27	47.59_{b}	14.16	24	53.08_{ab}	11.34	2.19	0.01	16.62**	0.08	3.06	0.02

Means with different subscripts are significantly different (Games Howell post hoc comparison). Family risk only (FR), language impaired only (LI), family risk and language impaired (FRLI) and typically developing (TD). High motor factor scores reflect poor performance.
*$p < .05$; **$p < .01$.

Table 2 Means and standard deviations for the four groups on the T1 and T2 executive function measures and SWAN Questionnaire ratings. Main effects and interactions from the 2 × 2 ANOVA are also displayed

	TD			FR			LI			FRLI			Main effect				Interaction	
													FR		LI		FR × LI	
Measures	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*N*	Mean	*SD*	*F*	ηp2	*F*	ηp2	*F*	ηp2
T1 Tasks																		
Visual search efficiency score	68	0.13_a	0.06	83	0.11_a	0.06	25	0.05_b	0.08	27	0.07_b	0.07	0.02	0.00	33.44**	0.14	2.18	0.01
Go/No-Go efficiency score	63	0.81_a	0.22	69	0.75_a	0.23	13	0.75_a	0.25	17	0.65_a	0.22	2.54	0.02	3.04	0.02	0.2	0.00
HTKS (/40)	60	13.17_a	12.22	67	8.63_{ab}	10.28	17	1.35_c	3.06	13	4.23_{bc}	5.07	0.16	0.00	14.80**	0.09	3.10	0.02
T1 executive function factor score	69	0.58_a	0.62	83	0.23_b	0.60	32	-1.08_c	0.65	29	-0.85_c	0.54	0.45	0.00	219.60**	0.51	9.47	0.04
T2 Tasks																		
Visual search efficiency score	69	0.18_a	0.05	82	0.16_{ab}	0.06	29	0.11_c	0.07	28	0.13_{bc}	0.07	0.20	0.00	31.17**	0.13	4.95*	0.02
ACPT efficiency score	66	0.17_a	0.06	80	0.14_b	0.10	27	0.10_{abc}	0.15	25	0.05_c	0.14	7.59**	0.04	25.89**	0.12	0.25	0.00
HTKS (/40)	68	25.76_a	9.93	79	21.90_a	11.59	28	9.68_b	11.67	27	9.70_b	8.26	1.29	0.01	70.17**	0.26	1.22	0.01
Block recall (/54)	69	16.86_a	3.36	82	15.51_{ab}	4.30	26	14.23_b	4.02	27	14.30_b	3.75	1.05	0.01	9.51**	0.05	1.28	0.01
T2 executive function factor score	69	0.47_a	0.51	83	0.11_b	0.90	32	-0.81_c	1.04	29	-0.52_c	0.72	0.08	0.00	62.38**	0.23	7.30**	0.03
T2 SWAN Questionnaire																		
Inattention (/63)	63	42.19_a	6.49	76	40.36_a	6.81	29	33.76_b	10.1	25	35.32_b	4.98	0.01	0.00	34.68**	0.16	2.21	0.01
Hyperactivity (/63)	63	39.71_a	6.87	77	40.05_a	7.45	28	35.39_{ab}	10.2	25	34.68_b	8.20	0.02	0.00	14.72**	0.07	0.17	0.00
Total (/126)	63	81.90_a	12.17	76	80.41_a	13.08	28	69.11_b	19.5	25	70.00_b	12.36	0.02	0.00	26.87**	0.13	0.29	0.00

Means with different subscripts are significantly different (Games Howell post hoc comparisons). Family risk only (FR), language impaired only (LI), family risk and language impaired (FRLI) and typically developing (TD).
*$p < .05$; **$p < .01$.

motor control; children at family risk showed an advantage compared to those not at family risk of dyslexia, although the effect size is small. The relationship between children's T2 motor factor score and their total DCDQ rating was moderate ($r = -.50$, $p < .01$) indicating that our behavioural measures of fine motor skills are sensitive to individual difference in symptoms of DCD.

Together the data suggest that in the preschool years children with language impairment have persistent weaknesses in their motor skills compared to children without language impairment.

Executive functions

At T1 and T2, children with language impairment (LI, FRLI) performed worse than children without language impairment (TD, FR) on the executive function factor score (a pattern also seen in all the individual measures of executive function[2]).

The significant Language Impairment × Family Risk interaction on the T2 executive function factor scores show that the effect of language impairment was significantly greater for children not at family risk of dyslexia (with post hoc comparisons revealing TD > FR > LI = FRLI). The correlation between T1 and T2 executive function factor scores (which were defined by slightly different measures) was strong ($r = .69$, $p < .01$) indicating that this factor has good longitudinal stability.

Together the data suggest that the children with language impairment have persistent weaknesses across several domains of executive function including selective and sustained attention, complex behavioural inhibition and visuospatial STM compared to children without language impairment.

T2 parental report data confirm the pattern of performance on objective measures of attention and behaviour control; children with language impairment were rated as having worse behaviour and attention skills than children without language impairment on the SWAN inattention and hyperactivity scales. The relationship between children's T2 executive function factor score and their overall SWAN rating was moderate ($r = .44$, $p < .01$) indicating that our behavioural measures of executive function are sensitive to individual difference in symptoms of ADHD.

Individual differences in motor skills and executive function; relationships with language ability

The data presented so far demonstrate that in the early years the difficulties experienced by children with language impairment are not limited to the verbal domain, but are also manifested on measures of motor skills and executive functions.

Figures 3 a and c show a moderate relationship between children's T1 and T2 motor skills and T1 language abilities ($r = -.69$, $p < .001$ and $r = -.60$,

$p < .001$ respectively; $r = -.66$, $p < .001$ and $r = -.54$, $p < .001$ with age controlled). Figures 3b and d also show that there is very strong relationship between children's executive function skills and their language ability at T1 ($r = .96$, $p < .001$; $r = .95$, $p < .001$ with age controlled) but that this relationship weakens by T2 ($r = .63$, $p < .001$; $r = .61$, $p < .001$ with age controlled).

There was also a strong relationship between children's motor and executive function skills at T1 ($r = -.70$, $p < .001$; $r = -.69$, $p < .001$ with age controlled) and T2 ($r = -.95$, $p < .001$; $r = -.95$, $p < .001$ with age controlled).

Predicting outcomes of children at family risk of dyslexia

Evidence suggests that individual variations in language skills predict which children at family risk of dyslexia will go onto develop reading difficulties (Snowling et al., 2003; Torppa, Lyytinen, Erskine, Eklund & Lyytinen, 2010); however, it also seems possible that variations in executive or motor skills will also predict variations in reading outcomes for these children. Our CFA (see Figure 1) showed that there were three separable factors assessed at time 1 (language, motor and executive function) but that the language and executive function factors were highly correlated ($r = .86$). A hierarchical regression model with age, and language skills as predictors showed that they accounted for 31% of the variance in literacy skills, and that motor skills then accounted for a further 4% variance (see Table 3). Due to the colinearity between the T1 language and executive function factors, executive functions were not a separable predictor after language skills were controlled (1% variance accounted for).

Discussion

The comorbidity between language learning disorders (e.g. dyslexia and language impairment) and disorders that are characterised by symptoms beyond the domain of language (e.g. DCD and ADHD) is frequently reported. Despite this relatively little is known about the overlap between these disorders in the preschool years. Understanding the overlap between developmental disorders is important for theory and practice and here we report novel findings from a study that investigated comorbidity in children at family risk of dyslexia before they started school.

Our findings clearly show that between the ages of 3 and 5 years, weaknesses in motor skills and executive functions are associated with preschool language impairment irrespective of the child's

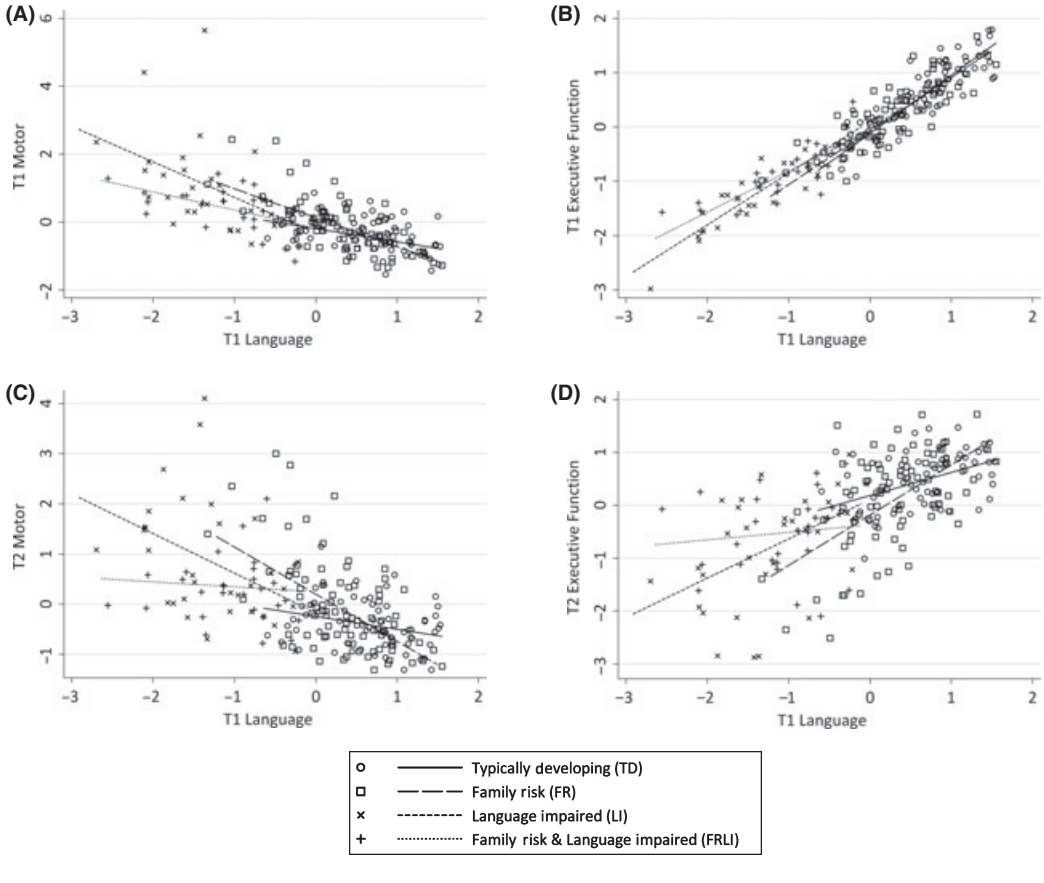

Figure 3 Scatter plots illustrating the relationships between T1 language and T1 motor (A), T1 executive function (B), T2 motor (C) and T2 executive function (D) factor scores

Table 3 Stepwise regression analysis predicting T2 literacy attainment from individual differences in language and motor skills at T1

Step	Variable	β	t	Unique R^2
1	Age	.07	4.12**	.15
2	Language	.23	2.97**	.16
3	Motor	−.31	−3.75**	.04

**$p < .01$.

family risk status. In this study, children with language impairment demonstrated significant weaknesses in motor skills and executive functions/attention, as assessed by both objective measures and parental report, compared to children without language impairment. Furthermore, these weaknesses were present at both T1 and T2 suggesting that they are persistent through the preschool period. Together these findings question the 'specific' nature of language impairment and suggest that many children with preschool language difficulties are likely to experience difficulties in other domains. Furthermore, our findings mirror the frequent comorbidity between language disorders, ADHD and DCD observed in school-aged children (e.g. Kadesjö & Gillberg, 1999; Willcutt & Pennington, 2000).

Children at family risk of dyslexia who do not have language impairment perform better than those with language impairment (LI and FRLI) on objective measures of motor skills and executive function. This group, however, still has weaknesses on these objective measures compared to TD children although they are not reflected in parental ratings of motor skills and behaviour/attention. A key question therefore is whether the comorbidity between dyslexia, ADHD and DCD is only apparent (or more apparent) in individuals who have a history of language impairment. The corollary of this would be that individuals with dyslexia who do not have a history of significant language difficulties are less likely to have comorbidities. This study is longitudinal and will allow a test of this hypothesis once the children reach the age when a reading disorder can be diagnosed.

Given the prevalence of motor and executive function weaknesses in children with language impairment and the correlations between individual difference in language, motor skills and executive functions that were observed, the data lend support to the view that the factors which place an individual at risk for language difficulties also influence the development of attention, behavioural control and motor skills (e.g. Bishop, 2002). Furthermore, although we do not yet know which of the children at family risk of dyslexia will go on to have reading difficulties the results from our regression analysis provide some preliminary support for the idea that multiple risk factors (T1 language skills and to a lesser but nevertheless significant extent T1 motor skills) play a role in predicting children's early literacy outcomes and thus are important in determining which children are most at risk of later literacy difficulties.

Another key finding is the very strong relationship between children's language skills and executive function in the preschool years. This is particularly important to bear in mind given research which has shown that executive functions, and behavioural control in particular, are important for school readiness (Blair, 2002) and later classroom learning (Blair & Razza, 2007; see Liew, 2012 for a review). Our finding raises the question of whether the proposed role of executive function in studies of school readiness and classroom learning can be separated from the role that individual differences in language skills may play. A future aim of our project is to investigate the role that executive functions play in children's academic outcomes; in particular, we are interested in how these skills impact on children's literacy development (e.g. the development of reading fluency, reading comprehension and spelling), once formal instruction commences. Indeed our current findings suggest that language may play a crucial role in mediating the relationship between executive function and literacy development. The longitudinal design of this study will allow us to consider whether the pattern of comorbidity between disorders changes over time and/or as a function of individual children's developmental trajectories and whether children with additional cognitive deficits beyond the language domain are more at risk of developing reading difficulties and thus more in need of early intervention.

Supporting information

Additional Supporting Information may be found in the online version of this article:

Appendix S1 Descriptive characteristics of the TD, FR, LI and FRLI groups.

Appendix S2 Tests and Procedures.

Acknowledgements

This study was funded by the Wellcome Trust Programme Grant 082036/B/07/Z. We would like to thank Lorna Hamilton and Ruth Leavett for their assistance with data collection, Emma Hayiou-Thomas for her support and the children and their families who participated in this study. The authors have declared that they have no competing or potential conflicts of interests arising from publication of this study.

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Key points

- There is considerable comorbidity between developmental disorders such as dyslexia, language impairment (LI), attention deficit/hyperactivity disorder (ADHD) and developmental coordination disorder (DCD).
- We investigated comorbid weaknesses in preschool children at family risk of reading difficulties, with and without LI, using measures of executive function and motor skills as markers of ADHD and DCD.
- Children with LI had comorbid weaknesses in executive function and motor skills compared to those without LI; Parents also rated these children as having more symptoms of ADHD (inattention and hyperactivity) and DCD (fine and gross motor coordination).
- Children at family risk of dyslexia without LI performed better on measures of executive function and motor skills than those with LI (LI and FRLI) but worse than TD controls.
- Children's language and executive function skills are strongly related in the preschool years and individual differences in language skills and motor skills both predict unique variance in children's early literacy skills.
- Future work should aim to investigate how comorbidity affects the manifestation of reading difficulties and how they impact on children's broader academic attainment and social/emotional development.

Notes

1. Given the age and low ability of some of the children, there were insufficient data from the diagnostic tests to determine language impairment status for 22 cases. For these cases, information from the separate TEGI screener subtests and the Preschool Repetition test (Seeff-Gabriel, Chiat & Roy, 2008) at T1 and CELF sentence structure test at T2 was used to come to a clinical judgement about group membership. Seventeen of the 22 cases were considered language impaired.
2. It is important to note that there was a reasonable amount of data missing for the more complex behavioural inhibition tasks (Go/No-Go and HTKS) particularly in the two groups with language impairment at T1 and thus the means reported here are likely to be an overestimation of the actual ability of these groups.

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Accepted for publication: 22 July 2013
Published online: 10 October 2013