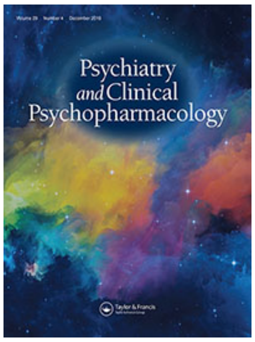

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Neurological deficits and comorbidity in children with reading disorder

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ABSTRACT

OBJECTIVES: Neuropsychological deficits were compared between three groups, i.e. RD (n = 12), RD (ADHD) (n = 12), and control group (n = 24) on neuropsychological tasks assessing Visuoconstructional ability, Postural Stability, and Language Laterality.

METHODS: Forty-eight children (age M = 12.5 years; 29 females, 19 males) were selected through purposive sampling procedure, from local primary schools. The participants were initially selected on the basis of Teachers Evaluation Checklist and then screened for RD and ADHD (combined type) using the Bangor Dyslexia Test and ADHD Clinical Parent Form, respectively. The groups were matched on nonverbal IQ (not less than on RSPM), Reading achievement estimate (≤90 on WRAT-3), age (11.5–15.3 years), and income. Visuoconstructional ability was assessed by scores on Rey Osterrieth Complex Figure Task (RCFT), while Postural Stability was measured by scores on Postural Stability subtest of Dyslexia Screening Instrument. Language Laterality was analysed through Dichotic Listening Words Test (DLWT).

RESULTS AND CONCLUSIONS: Results indicated that the group with RD (ADHD) performed significantly poor on all these tasks as compared to NC and RD (pure) group. Although the results are restricted to limited sample size, findings of the study may help in isolating the specific neuropsychological deficits related to reading disability and comorbidity which can provide important clinical information regarding etiology of the RD-ADHD connection and future treatment.

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KEYWORDS
Neuropsychological deficits; visuoconstructional ability; postural stability; language Laterality; attention-deficit hyperactivity disorder

Professionals who educate and treat individuals with developmental difficulties speak of diagnostic categories while referring to developmental disorders. Researchers and clinicians have attempted to classify childhood developmental disorders into discrete diagnostic categories such as those found in the Diagnostic and Statistical Manual of Mental Disorders V (DSM-V), American Psychiatric Association [1]. In many cases, however, children with these disabilities do not display just one discrete disorder but several disorders. For example, children with reading disabilities often have symptoms of attention-deficit/hyperactivity disorder (ADHD), and children with ADHD frequently meet criteria for some other psychiatric condition. When this occurs, the term comorbidity is used to refer to the fact that few children fit neatly into one single discrete disorder. The current study emphasizes the importance of assessing comorbidity in terms of neuropsychological functioning in the areas of visuoconstructional ability, postural stability, and receptive vocabulary.

Reading disorder (RD) is a developmental disorder characterized by specific impairment in a single-word reading, reading fluency, and reading comprehension usually as a result of poor phonological processing [2,3]. RD affects the ease with which children learn to read and spell. Individuals with reading difficulties also show more emotional and behavioural disturbances than those without a history of reading difficulty [4]. The first description of a specific RD was an 1896 case study in the British medical literature of a "bright and intelligent boy" who had great difficulty learning to read.

RD and ADHD significantly co-occur as comorbid [5–9]. Children diagnosed with hyperactivity often show poor educational attainments and children with learning disabilities show an increased risk of hyperactivity and other behavioural problems [10–12]. It seems unlikely that these associations are simply a reaction of the increased likelihood that children with multiple problems will be referred to clinics: several epidemiological studies indicate that behaviour problems including hyperactivity and learning disabilities.

Reading-related differences in attention are of particular concern because of the high incidence of comorbidity between RD in children and ADHD [7]. Jagger-Rickels et al. [13] have discovered the role of caudate and frontal regions in both RD and ADHD groups of children (aged 8–12 years) to be poorly developed then healthy controls. In addition to this, Marie-Ève Marchand-Krynski et al. [14] observed predictors of sequential motor movement abilities in a sample of 215 children with dyslexia and/or ADHD and found little variation in poor visual working memory in

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children with dyslexia, ADHD, or both as comorbid. Given the higher incidence of attention-related deficits in the population with RD, it is plausible that variables like attention could explain much of the shared variance between individual differences in reading and sensory thresholds.

A child with the reading disorder typically presents problems with segmentation, the process of recognizing different phonemes that constitute words or with blending these sounds to make words. Additionally, visual sequential memory problems interfere with reading comprehension. Several studies have reported that RD is associated with sensory deficits in the processing of particular visual and auditory stimuli [15,16]. Psychological, educational, and brain research over the past 20 years consistently has shown that reading disorder is a disorder related to the language system. Reading disorder involves deficient processing of individual linguistic units, called phonemes, which comprise all spoken and written words. Recent research has shown that reading directly reflects spoken language. Slow phoneme processing appears to be the primary cause of reading problems. Poor ability in any part of this process (e.g. segmenting/blending, speed, memory) adversely affects overall reading ability.

Several studies focusing on auditory temporal processing theories provide evidence of both receptive and expressive vocabulary skill deficits in children with dyslexia (e.g. [17–19]). Initial studies based on auditory temporal hypotheses have drawbacks in terms of small sample size and ill-defined criteria for their selection. Therefore, there is no way to know what the stimulus intensity was at the ear or whether this intensity was the same for all participants. In addition, many of the studies in this area do not specifically exclude children with SLI in order to ensure that findings reflect deficits in children with RD rather than children with SLI who may be included in RD groups [20].

Children with dyslexia are found to exhibit subtle impairment in naming pictures and words. In one recent study, Maaike Vandermosten [21] examined the role of statistical learning in phoneme presentation in a sample of 58 children with dyslexia and found that children made less use of the statistical cues based in oral language which resulted in the less clear presentation of phoneme categories in the children. Thus, failure to establish such contact could provide difficulty in the written language subsequently written language. A recent study examining structural / functional brain differences in dyslexia have persistently shown the evidence about brain differences in early childhood, before formal reading instruction in school, which supports the importance of early identification and intervention. Psyridou et al. [22] conducted a follow-up study on reading outcomes and highlighted that delays in receptive vocabulary skills is vital to recognize as an early risk factor.

Attentional composition (i.e. dichotic listening) is another factor which is quite necessary for the acquisition of appropriate reading skills. In a study carried out by Kreshner et al. [23], adults with moderate and severe dyslexia and normal controls were tested on their ability to shift attention between ears for immediate recall. Using blocks of pairs of consonant–vowel syllables for counterbalancing left ear first or right ear first ordered conditions, results indicated that those with severe levels of dyslexia performed poorly in terms of switching attention to the left ear, whereas both groups having dyslexia were poorer switching attention to the right ear. Similarly, a review of research evidence over the past 30 years has shown that perceptual attributes interact with cognitive factors (such as auditory language processing) to shape asymmetry of auditory language information processing.

Receptive vocabulary is the ability of a person to comprehend and respond despite having an inability to produce words. Individuals with dyslexia have often been found to have a deficiency in the language lateralization causing poor receptive vocabulary.

Receptive vocabulary can be measured using various psychological instruments. Dichotic Listening Test is one of the psychological tools used to examine language lateralization. Secondarily, it is a measure of temporal lobe functional integrity.

Broadbent [24] developed it initially to investigate the ability of an individual to attend to two signals simultaneously, one to each ear [25]. Kimura [26] modified the task by using simple one-syllable numbers in a set of three pairs, after which the subjects were asked to repeat as many of the numbers as possible. Kimura noted that in epileptic patients with documented left hemisphere speech dominance, right ear recall was better than recall from the left ear [24].

Very few studies have included effects of RD on motor control and balance. Analysis conducted by Nicolson and Fawcet [27] has shown that cerebellum and procedural deficits in the neural network may be associated with specific language problems experienced by individuals with dyslexia [26]. Baldi [28] examined daily motor characteristics in 96 children aged between 5 and 12 years children with a diagnosis of specific learning disorder (SLD) and compared their performance with those of children with developmental coordination disorder (DCD) and typically developing controls. They used the Italian version of the Developmental Coordination Disorder Questionnaire to assess children's coordination in everyday functional activities. Findings showed that children with SLD had a large deviation in scores from typically developing children in a few motor skills during ordinary activities.

Children with ADHD often experience delays in acquiring competence completing fundamental motor skills. Ziereis and Jansen [29] examined the impact of physical activity on executive functions performance and tested the motor learning effects of knowledge performance task among 31 boys with ADHD. The sample was randomly recruited into either a treatment or a control group. It was observed that PKP feedback improved motor skill performance learning among children with ADHD. Mokobane, Pillay, Meyer [29] examined deficits in fine motor skills in primary school children with ADHD. They used The Disruptive Behavior Disorders Rating Scale with educators and parents. Children with ADHD (predominantly inattentive subtype) and ADHD (combined subtype) showed poor performance than the control group on a range of fine motor skills.

Although the correlation between IQ and word reading is considerable, it is also clear that the outstanding variance in word reading after controlling for IQ is significant and is largely of genetic origin for both children and adults within generally literate populations [30]. Because many of the tasks employed to estimate sensory processing abilities can be demanding of both attention and general intelligence, research has shown uncertainty regarding whether correlations between basic sensory processing and reading are independent of the effects of general cognitive skills. In a recent study, researchers observed abnormal visual processing of words in a group of 9-year-old typically reading children and two groups of children diagnosed with dyslexia by using EEG recordings on a visual task. The study suggested possible functional connectivity to be dependent upon reading dysfunctionality that is beyond any group differences. Peschard et al. [31] reported that individual differences in Wechsler full-scale IQ accounted for most of the shared variance between single-word reading and visual contrast sensitivity in 3rd- through 12th-grade children. These studies confirm the need to control for the effects of IQ to clarify the relation between sensory processing performance and reading.

Given the literature around clinical utility, tests such as Dichotic Listening Words Test, Dyslexia Screening Test and the Rey–Osterrieth Complex Figure Test were used to address the following questions:

(1) Does comorbidity lessen the performance of individuals already with a disability, on neuropsychological tasks?
(2) How can performance be explained by comorbidity?
(3) Is there any influence of (1) genetics, (2) Income background and Intelligence, on performance of these tasks?

Method

Participants

Clinical presentation of children with symptoms of ADHD or RD and other related disorders are not well reported in Pakistan due to lack of awareness regarding reporting of the symptoms. Therefore, for the current study, local schools were approached. The sample size was estimated by using following criteria for clinical populations: $n = N/(1 + N{*}e\hat{\ }2)$ [32]. The sample size was estimated to be 24 for the three clinical groups involved in the present study.

The sample consisted of three groups of children, i.e. 24 (12 boys and 12 girls females) with a confirmed diagnosis of ADHD, while 24 (12 boys and 12 girls) were healthy controls. Amongst the children with ADHD, 12 had the comorbid reading disorder and (criteria discussed below). The age range of the sample was between 11.5 years and 15.3 years (mean = 12.5 years). The children were recruited from three local federal government schools. All the children could understand and comprehend English besides which was their mother tongue. Data from children with RD and ADHD were compared with those from an age-matched group of healthy children, who had been recruited from the same schools but with no complaints related to attention or learning.

Study groups

The study included three groups i.e. RD (pure), Comorbid Group (RD+ ADHD) and Normal Controls (NC). All children were diagnosed with RD and ADHD confirmed by a multidisciplinary clinical diagnostic assessment. The assessment comprised of a semi-structured clinical diagnostic interview (face-to-face interview with parents and teachers), standardized behaviour rating scales completed by the parents and teacher and Comprehensive Child Assessment using Dyslexia Test. The Barkley Clinical Parent Interview covers the child's development and current behaviour and uses the DSM-V criteria for externalizing and internalizing disorders of childhood [33]. The Bangor Dyslexia Test has been used widely to record overall neuropsychological assessment of children with the reading disorder (dyslexia). The form includes 10 items. Reliability and validity for the test are high, with an alpha of .84 for diagnosis [34].

The child assessment included the arithmetic, spelling and reading subtests of the Wide-Range Achievement Test-3 [35], and Ravens Standard Progressive Matrices (RSPM) [36]. Children with an intelligence quotient (IQ) score of less than 80, any evidence of neurological dysfunction, poor physical health, uncorrected sensory impairments, or a history or current presentation of psychosis were excluded from the study.

Diagnosis of reading disorder

For the present study, a definition of low achievement in a single-word reading was used to classify reading difficulties. Specifically, children with a composite standardized reading score of less than 90 (i.e. less than 25th percentile) were classified as having comorbid reading difficulties. The composite reading score was calculated from the average of the standardized scores on three measures of reading; the subtests of WRAT-3.

Comparison group

Parents had confirmed on a questionnaire that their child was in good physical health, had no known problems with attention, behaviour or learning, nor any neurological dysfunction, sensory impairment, major medical or mental health problems, and were not on any medication for any clinical condition. The mean age of children in this comparison group was 12.5 years (SD 1.3 years).

Measures

The study employed standardized neuropsychological tools in order to assess executive functions performance by the two groups. Brief description of the tools is discussed as under:

The Barkley Clinical Parent Interview and Bangor test were administered independently by trained researchers who rated the behaviour on a four-point scale of severity and frequency based on the elicited descriptions of behaviour. To be classified as ADHD, children had to meet DSM-V criteria for ADHD, defined as at least 8 of 15 inattentive or hyperactive-impulsive symptoms, or both. To ensure pervasive impairment, children were required to meet criteria for ADHD in the parent or teacher interview but also exhibit a minimum of four inattentive or four hyperactive-impulsive symptoms according to the other informant.

The *Rey Osterrieth Complex Figure Test* provides an objective and standardized approach to scoring drawings based on the widely used 36-point scoring system. The same scoring criteria apply to all three drawing trials. Each of the 18 scoring units is scored based on accuracy and placement criteria. Unit scores range from two (*accurately drawn, correctly placed*) to zero (*inaccurately drawn, incorrectly placed, unrecognizable, omitted*).

Postural stability

The Postural Stability test is drawn from the Dyslexia Screening Test. Subjects are asked to stand up straight, blindfolded, with feet together and arms alongside. They are pushed in the lower back and must try to stay as still as they can. Pushing is performed using the balance tester from the DST.

Dichotic listening words test

The dichotic listening word test, developed initially by Canivez [30], is a measure of language lateralization and temporal lobe functional integrity. The Dichotic test exists in two forms i.e. dichotic word and music test. The present study utilized word form only to measure listening vocabulary of children with disability. It is a standardized test with an alpha reliability of 0.69 [37].

Procedure

The study was approved by local research ethics review committee ensuring that all standards for the ethical considerations laid down by the APA are met. The study was conducted through three phases. Phase one started soon after demographics collection. For the first phase, depending on the condition, the subjects both copy the Rey Complex Figure directly onto a piece of paper or mentally in their head and then, without prior warning, reproduce it from memory. Following a 3-min delay filled with talking, a clean sheet of paper is presented and the copy figure is drawn again After the 3-min recall task is completed, the time leading up to the 30-min task is also filled with talking; however, there is no mention of another recall being given. Once it has been 30 min after the first administration of the RCFT, another clean sheet of paper is presented and the subject draws figure again there is no time limit on this recall task. To score the RCFT, the Meyers and Meyers [38] scoring system was used. The figure is broken down into 18 scoring units. A score of 0, 0.5, 1, or 2 is assigned to each unit of the figure based on the accuracy and placement criteria. Unit scores are then summed to obtain the raw score for that drawing. For each unit of the figure, a score of 2 is assigned if the unit was drawn accurately and placed correctly. A score of 1 is assigned of the unit was drawn accurately or placed correctly. A score of 0.5 is assigned if the unit was drawn inaccurately and was placed incorrectly, but is still recognizable. A score of 0 is assigned if the unit was omitted altogether or is not recognizable. Using the Meyers & Meyers scoring system, a drawing is never penalized twice for the same error. The scores for the 3- and 30-min recall for each participant were averaged to get one recall score.

In the second phase, Postural Stability test was administered. There were three trials per child, administered and scored according to the instructions provided in the manual. Scores ranged from 0 to 6: 0 rock solid, 1 slight sway, 2 rises up on toes, 3 small step forward/marked sway, 4 marked step forward, 5 two controlled steps forward, and 6 marked loss of balance.

Lastly, each child was given a dichotic listening words task. The task involves simultaneous exposure to two different stimuli from both ears. Each stimulus consisted of a set of three words each. The participants were asked to attend to any of these stimuli and recall. Scoring was done according to the instructions provided in the manual.

Ethical considerations

The research followed the ethical standards prescribed by the American Psychological Association. Informed consent was taken from children and their parents / guardians and school administrations. Participants presenting with serious clinical conditions as identified through the study were referred to the appropriate clinical services in the local area.

Analysis

Data were analysed using statistical Packages for Social Sciences (SPSS). Frequencies, percentages, and Chi-square analysis were computed for demographic variables. The analysis of variance (ANOVA) was used to assess the neuropsychological differences between the three groups, i.e. NC, RD (ADHD) and RD (Pure).

Results

Demographic characteristics

A 3 (groups) × 3 (variables) factorial design was used. Table 1 presents *t*-test analysis and mean scores of individuals with and without RD on demographic variables and measures of non-verbal IQ and RD. The mean age of the two groups (i.e. 12.5 years) was not statistically different, but the mean difference on monthly income was significant ($p < .001$). Similarly, the mean scores were expectedly low on WRAT as a measure of achievement level. Besides having ADHD as a comorbid, the individuals with RD also had Oppositional Defiant Disorder, ODD (21%), Conduct Disorder, CD (1%), Separation Anxiety Disorder, SAD (5%), Overanxious Disorder, OAD (16%), Mild Depressive Episode, MDE (3%) and Dysthemia (4%) as measured by ADHD Clinical Parent Interview (Figure 1). Eighty per cent of the individuals belonged to urban areas, while 85% of the total sample were bilingual (i.e. could understand and understand both Urdu and English) (see Table 1).

Table 1. Sample characteristics ($n = 48$).

	NC ($n = 24$)		RD (ADHD) ($n = 24$)		
	Mean	(SD)	Mean	(SD)	*T*
Age	12.5	2.3	12.3	2.2	n.s.
Income	8000	2.6	3600	1.5	3.56**
RSPM (IQ)	96.5	10.6	91.6	10.6	n.s.
WRAT standard score	130	6.8	112	6.0	11.62**
-Reading standard score	81.2	1.2	75	3.6	5.36**
-Spelling standard score	80.4	2.0	79.3	2.6	8.35**
-Arithematic standard score	83.4	2.0	74.6	1.0	6.56**

Notes: RSPM, Ravens Progressive Matrices; WRAT, Wide-Range Achievement Test; ss, standard score; n.s: not significant, NC, normal controls; RD, reading disorder.
**$p < .001$.

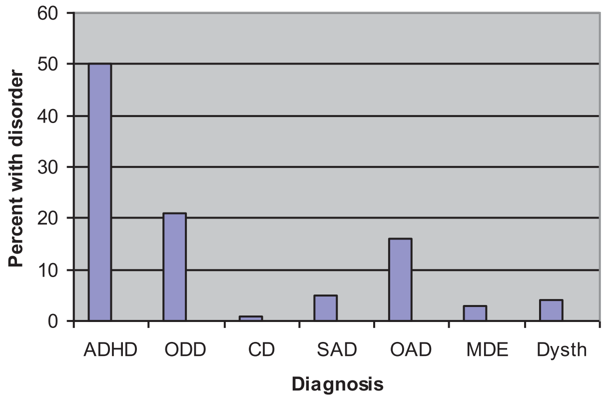

Figure 1. The prevalence of comorbid diagnosis in individuals with RD.

Performance on visual memory task

The performance of the two groups i.e. RD and Controls were compared on a task assessing visuoconstructional ability (RCFT). ANOVA was applied to determine between-group differences. Table 2 summarizes the scores obtained by the three groups (RD (pure), RD (ADHD) and NC) on RCFT, PS and DLWT. The results on RCFT suggest that individuals with RD have rather severe problems in memory image retention and organization as compared to controls ($F = 32.5$, $p = .001$). The group with pure RD showed disturbed delay recall than the group with both RD and ADHD who had difficulty with reproducing immediate recall (Table 2).

Performance on postural stability task

For postural stability, the mean score of three trials was taken as final score because on any trial, a subject might be able to resist the push, or on the contrary, might lose their balance by chance; taking the mean, therefore, allows one to disregard outlying trials. Table 2 shows the data obtained for the Stability tasks. ANOVA was used to compare the groups (RD and Controls). Significant differences were found in the motor task ($F = 13.9$, $p = .02$). It can also be seen from the scores that

Table 2. *Post hoc* analysis (ANOVA) of neuropsychological differences ($n = 48$).

	Groups			
	NC ($n = 24$)	RD ($n = 12$)	RD+ADHD ($n = 12$)	*F*–test
	Mean (SD)	Mean (SD)	Mean (SD)	
Immediate Recall	18 (1.2)	11 (3.2)	6 (1.6)	
RCFT				32.5**
Delayed Recall	15 (1.3)	9 (3.5)	15 (2.4)	
PS	5 (1.6)	12 (4.0)	14 (3.9)	13.9**
Left ear	39 (4.3)	48 (3.6)	36 (5.6)	
DLWT				13.7**
Right ear	53 (2.5)	24 (2.0)	30 (2.5)	

Note: RCFT, Rey Complex Figure Test; PS, postural stability; DLWT, dichotic listening words test.
**$p < .001$.

attention difficulties, in the presence of ADHD have resulted in more balance problems than that of RD alone.

Language laterality and comorbidity

Table 2 represents scores on dichotic listening words test [24], where the individuals with RD showed left hemispheric dominance as they scored high on left ear vocabulary consonants than that of right ear. Majority of the controls attended more to right ear vocabulary than that of left ($F = 13.7$, $p = .02$).

Discussion

This exploratory study examined neuropsychological differences in the presence of comorbidity on a small sample of 48 school children of 11–15 years with and without RD. Results indicated that individuals with RD are significantly poor in performing neuropsychological tasks. The findings also suggested that these executive functions were more disturbed in individuals who had ADHD as a comorbid condition. The finding that attention and impulsivity problems, as observed in ADHD can interfere with learning problems whose cumulative impact may be poor acquisition of new information has been proved by various researches [39,40]. The findings of the present study also correlate with that of recent researches which indicate that ADHD causes significant impairment in performing executive functioning and reading performance [5,41,42]. Some recent findings from neuroimaging studies of ADHD have also reported structural anomalies in the cerebellum, basal ganglia, and prefrontal cortex [43,44].

The results also showed that 75% of the individuals with RD had a genetic basis of this disorder which explains their performance levels. Individuals with RD were also identified as having ODD, CD, SAD, OAD, MDE and Dysthemia besides ADHD (Figure 1). Gender proportion of the sample was unequal, thus statistical analysis for comparison could not be made, however; it can be one of the factors responsible for poorer performance. It has been proved through research evidences that boys are more prone to develop hyperactivity disorder than girls [45].

The first question to address is whether the performance on neuropsychological tasks was explained by the comorbidity with other developmental disorders. Additional analysis (ANOVA) was done to compare within-group differences on these tasks. Results showed that out of 24 individuals with RD, 12 had pure RD, 12 also had ADHD, and 5 had ODD, while 3 had OAD. Although the results cannot be generalized, but the present data suggest that if individuals have any form of comorbidity, observed effects on motor, memory, and stability tasks will tend to increase in incidence and severity.

Memory functioning and perceptual organization

Results suggest poor delayed recall among individuals with ADHD as comorbid partially because of lack of attention and impulsivity. It has also been observed that most of the tasks involved in the present study required divided attention or dual trials. As for instance, in RCFT, the subjects have to repeat the visualized image after a short span. Similarly, on DLWT, two stimuli are activated simultaneously through both ears and the subject has to divide his\her attention. This could possibly affect the performance of the comorbid group on these neuropsychological tasks as explained by other studies as well [13,46].

Cerebellar influence in the form of postural stability was also assessed in this study which suggested that the comorbid group had poor stability. This can partially be explained by their brain structures and size of the cerebellum [47] which suggests less posterior temporal cortex activation. Another factor could be the presence of several developmental disorders besides ADHD which could intensify the poor performance. The findings of the present study that RD has better coordination than the comorbid group has been supported by the studies which suggest poor postural stability among children with dyslexia [48]. Attention difficulties faced by children with ADHD cause poor stability.

In conclusion, the present study investigated neuropsychological differences among RD with and without ADHD. The individuals performed visual retention, stability, and lateralization tasks while results confirmed the findings of previous studies that comorbidity intensifies worst performance of executive functions. The findings of the study, though limited to the small sample size, can still be of immense clinical importance since RD is being recognized particularly with reference to cognitive and motor functions. Together, the factors identified in the present findings can be helpful in providing a sound basis for its development and assessment. It is, however, important to carry on follow-up researches to validate the findings and explore new variables.

Disclosure statement

No potential conflict of interest was reported by the authors.

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