# Dyslexia and Visuospatial Ability in Maltese Male Adolescents

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## Abstract

*A number of studies suggest that dyslexia is associated with enhanced visuospatial ability but the empirical evidence is inconsistent and there are numerous methodological issues. This study examined visuospatial ability among dyslexic and asymptomatic (non-dyslexic) adolescent boys aged 12 years. Thirty-six Maltese participants constituted the research and comparison groups. All participants were assessed on the age-appropriate section of the Spatial Reasoning Test and they were matched by age, ability measured by Ravens Progressive Matrices, socio-economic status and the type of school attended. Overall, the degree of visuospatial ability of the two groups was similar. A statistically significant advantage for the asymptomatic over the dyslexic group was evident on one task only, Hidden Shapes. In contrast, dyslexics outperformed non-dyslexics on the other three tasks constituting the battery including Jigsaws, Wallpaper and Right Angles subscales but the difference did not reach statistical significance. Although these findings did not support the notion that dyslexic individuals were more visuospatially endowed than a comparable, asymptomatic group of peers, the possibility of an underlying difference could not be discounted altogether. A number of reasons for the results obtained were examined including the relatively small sample size, participants' age, verbal mediation strategies and the nature of the visuospatial tasks. However, the findings that both groups had similar average results, with the dyslexic group having greater variation on the Hidden Shapes scale, smaller variation on Sections, Jigsaws and Wallpaper scales and the small tendency of this group to outperform the non-dyslexics group on a number of subscales warrants additional exploration of dyslexia and visuospatial ability.*

***Keywords:*** *dyslexia; visuospatial skills; male adolescents; Maltese; state secondary school.*

## 1. Background

Children with dyslexia experience a range of difficulties that are associated with literacy and sometimes numeracy. Such difficulties permeate their learning and some students leave school with minimal qualifications (Snowling, 2013). Contrary to the praxis in education where labelling is intentionally avoided, the label of dyslexia has been used to support affected learners, secure resources, provide specialist teaching and award access arrangements (Ho, 2004).

Dyslexia is described as the condition where individuals experience difficulties in the acquisition of literacy. It is strongly associated with inadequate fluency in reading and writing (Ise & Schulte-Körne, 2010; Wiseheart, Altman, Park, & Lombardino, 2009). Furthermore individuals with dyslexia may show specific abilities such as design, problem solving, creative, interactive and oral skills (Rose, 2009). The prevalence of dyslexia varies between 3% and 7% depending on the criteria used for its diagnosis (Hulme & Snowling, 2009). In China the prevalence of dyslexia is around 4% (Sun et al., 2013), in Japan 6% (Macita, 1998), in the USA 8.5% (Hillis & Caramazza, 2005) and in Italy between 3% and 5% of the total population (Stella, 1999). In the United Kingdom, where there is a long tradition of research in this area, developmental dyslexia affects about 9% of the population (Clarke, Snowling, Truelove, & Hulme, 2010; Nation, Cocksey, Taylor, & Bishop, 2010).

In the light of a positive stereotype of a bright, even gifted individual experiencing literacy difficulties (Elliott & Gibbs, 2008; Rice & Brooks, 2004), a number of scholars have even gone as far as calling dyslexia a "gift", describing dyslexic individuals as highly creative, intuitive and good at problem solving at the three dimensional level, effectively possessing enhanced visuospatial skills (Davis & Braun, 2010; Eide & Eide (2011).

Generally speaking, the Maltese education system is similar to the British one. These last two decades have seen an increased emphasis on the relevance to the local and the wider European context particularly after EU accession. Dyslexia first became legally acknowledged in the UK in 1970 through the Chronically Sick and Disabled Person's Act but it was 36 years later that in Malta the Education Amendment Act (2006) acknowledged “specific learning difficulties”.

Visuospatial ability is generically defined as “the ability to generate, retain, retrieve and transform well-structured visual images” (Lohman, 1996, p. 112). However, there are different conceptualizations of visuospatial ability as well as a variety of instruments that are used to measure it (Höffler, 2010). In the absence of consensus, Maeda and Yoon (2013) suggest that visuospatial ability consists of two correlated, but theoretically separable core dimensions: spatial visualization (SV) which usually involves the spatial transformation of objects, and spatial relation/orientation, which does not necessarily involve spatial transformation. They make a case for mental rotation ability being important in science, technology, engineering, and mathematics (STEM) disciplines because these subjects involve geometric problem-solving or molecular structure representations of chemical materials, which require a strong visuoperceptual sense to grasp the dynamics and structures of objects in 3-D space.

On the basis of the conducted review of literature, this study uses Linn and Petersen’s (1985) three components of visuospatial awareness constructs because these components are clearly operationalised and measure spatial visualization, mental rotation and spatial perception. These three processes represent the aspects of spatial awareness that children are expected to employ when administered paper-and-pencil tests (Maeda & Yoon, 2013). *Spatial visualization* refers to spatial ability tasks that involve complex multi-step manipulations of spatially presented information relying on spatial perception and mental rotation. *Mental rotation* refers to the ability to rotate a two- or three-dimensional figure rapidly and accurately. *Spatial perception* involves the determination of spatial relationships with respect to the orientation of the test takers’ own bodies (Linn & Petersen, 1985).

## 2. Dyslexia and Language Orthography

Skilful reading requires adequate language comprehension and fluent word identification (Vellutino, Fletcher, Snowling, & Scanlon, 2004). Learning to read depends on the knowledge and skills necessary to interact with the environment and this is done through two main modalities; visual and linguistic coding. Linguistic coding assumes a range of phonological coding skills that include but are not limited to phonological awareness. This is the process which most readers employ to develop letter-sound associations and effectively the alphabetic principle. In theory the prevailing opinion is that average readers usually grasp the alphabetic principle by segmenting spoken words into their constituent phonemes. This helps them learn the associations between sound segments and letters in printed words (Vellutino et al.). The alphabetic principle gives children the skill to decode new words that they have not encountered previously (Snowling, 2013). Young children experiencing literacy problems usually manifest difficulties in developing phonological awareness which in turn affects the acquisition of letter-sound knowledge (Carroll & Snowling, 2004). Dyslexic readers experience problems with phonological decoding and hence word reading and this is most evident when attempting to read novel words (Rack, Snowling, & Olson, 1992).

Beginning readers potentially experience three issues when starting to read: availability, consistency, and granularity of spelling-to-sound mappings (Ziegler & Goswami, 2005). The consistency problem refers to the fact that some orthographic units have multiple pronunciations and that some phonological units have multiple spellings leading to issues with homographs (the noun and verb senses of the word ***bear***) and homophones (***bear/bare***) (Kreuz, 1987). The degree of inconsistency varies between languages making it likely that emergent and novel readers would develop their reading differently across languages. Phonological recoding and reading is facilitated in regular orthographies because the high consistency of the grapheme–phoneme correspondence encourages readers to rely on the small grain size of the phonological unit. Thus, highly consistent letter-sound relationships in transparent orthographies suggest that the size of the basic phonological unit is smaller than in orthographies where letter-sound relationships are less consistent.

This is relevant to the present study because the participants were regularly exposed to two languages, Maltese and English. Modern Maltese is descended from Siculo-Arabic (Voegelin & Voegelin, 1977) and was gradually enriched with many additions from Italian, Spanish and English positioning it on the continuum between Semitic and Romance (Comrie, 2009). Maltese possesses a shallow orthographic structure with consistent grapheme-phoneme correspondence and a fine granular structure which facilitates reading. In first language users, the fine granular structure of Maltese may mask the difficulties that dyslexic children experience in English which has an opaque and less finely grained orthography (Patel, Snowling, & de Jong, 2004).

## 3. Visuospatial Abilities and Dyslexia

Individuals with dyslexia are overrepresented in occupations and activities that require visuospatial skills and creative thinking, such as art and design, architecture and inventing (Bacon, Handley, & McDonald, 2007). Art and design related disciplines attract higher proportions of students with dyslexia than their traditional academic counterparts (Symonds, 2005; Winner et al., 2001; Wolff & Lundberg, 2002). Correspondingly, between 10% and 15% of students enrolled in art and design courses in the United Kingdom have dyslexia which is a higher percentage than in other courses (Brigden, 2001). This prompts the question of whether students with dyslexia have better than average developed skills in the areas of spatial awareness and creativity or whether this is a result of avoiding traditional academic routes (Alden & Pollock, 2011). Students with dyslexia are much less likely than average readers to be involved in professions such as science, computing, management and finance due to these occupations' reliance on written work, numerical and symbolic processing and severe time pressure (Taylor & Walter, 2003).

Studies related to dyslexia, visuospatial abilities, creativity and artistic talents span three decades (Galaburda, Sherman, Rosen, Abolitiz, & Geschwind, 1985; West, 1999; Wolf & Lundberg, 2002). Neurological investigations of people with dyslexia have led to the speculation that while it is true that dyslexia constitutes a deficit in literacy skills, it seems that it may lead to the enhancement of other abilities, essentially what Geschwind (1982) referred to as the *pathology of superiority*. The same processes that lead to changes in parts of the brain augment other cognitive functions (Galaburda et al., 1985). While visuospatial skills may be stronger in adult men with dyslexia they may not be identifiable due to the lack of suitable diagnostic procedures. (Brunswick, Martin, & Marzano, 2010).

Von Károlyi, Winner, Gray, and Sherman (2003) suggest that dyslexics have relative strengths in visuospatial areas while Everatt, Steffert, and Smythe (1999) suggest that their spatial skills are neither inferior nor superior to the rest of the population. Everatt (1997) suggests that in dyslexic individuals such talents require a certain level of maturation to come to the fore and may not be evident until such maturation is achieved. Unfortunately many studies differ significantly in their methodological approaches and findings may be artefacts of the different tests and statistical methodologies used as well as the typically small sample sizes of most of the studies (Brunswick et al., 2010).

Everatt et al. (1999) used paper-and-pencil tests to compare groups of dyslexic and non-dyslexic adults, teenagers and children on a number of measures involving insight and creativity. While finding evidence for superior skills on tasks requiring fluid ability in dyslexic adults, they found little evidence for differences between dyslexic and non-dyslexic adult groups in terms of visuospatial skills, often associated with the functioning of the right hemisphere. Von Károlyi (2001) compared dyslexic and non-dyslexic high school students on two computer-based visuospatial tests in two separate experiments: one called *Celtic Matching Task* and the other *Impossible Figures Task*. In the *Celtic Matching Task* requiring participants to select one from four similar figures that matched exactly the target figure more than three quarters of the non-dyslexic group (17 of 22) correctly matched the item, while only just over half the dyslexic group (23 of 40) selected the correct match. Although dyslexic males performed relatively worse than did non-dyslexic males in this task, the difference was not statistically significant. In the *Impossible Figures Task* students had to determine as quickly and as accurately as possible whether a given figure was impossible or not in three-dimensional space. Individuals with dyslexia were significantly faster at correctly identifying impossible figures than other individuals, but were no more accurate.

Attree, Turner, and Cowell (2009) assessed adolescents with dyslexia and their non-dyslexic peers on a visuospatial test. Forty-two participants equally divided between the dyslexic and non-dyslexic groups were administered a computer-generated virtual environment test. This test assessed incidental spatial memory and was deemed to mimic everyday real-life spatially oriented activities. In this test dyslexic adolescents achieved significantly higher scores than their non-dyslexic peers. Attree et al. also ran two standard paper and pencil tests for visuospatial ability, the BAS *Recall of Designs* and *Pattern Construction* subtests with no significant difference between the two groups. They claim that these findings are commensurate with previous research by Geschwind and Galaburda (1987) which show that on standard paper-and-pencil tests of spatial ability, dyslexic individuals perform equivalently to or slightly below the general population. Here lies the Achilles heel of the area and illustrates a typical case in point. While the *Recall of Designs* is a paper-and-pencil two-dimensional test involving abstract diagrams the *Pattern Construction* subtest is a three dimensional activity using plastic blocks, rotated and manipulated to replicate two dimensional patterns. It is not justifiable to compare these two directly because they are tapping different levels of spatial ability.

Brunswick et al. (2010) investigated the hypothesis that dyslexia may be associated with higher visuospatial abilities by assessing 41 undergraduate and postgraduate students matched on IQ. Twenty participants were dyslexic (10 men and 10 women) and the remaining 21 participants (10 men and 11 women) were not. Apart from the measures used to balance the groups, participants were tested on paper-and-pencil visuospatial tests as well as a virtual reality test, the Herman Virtual Reality environment; there were no clear instances of the dyslexic group outperforming the unimpaired readers on the paper-and-pencil tests or on the virtual reality test. The evidence indicates that any findings of differences in visuospatial skills between dyslexic and average readers are inconclusive but computer-based virtual environment tests appear to identify dyslexic groups as being more skilled in this domain.

Based on the literature review, it seems that on the one hand dyslexic individuals may be more adept at dealing with information in a visuospatial way. This renders phonological segmentation, sounding out of letters, syllable level representations and prosodic structure which are deemed to be essential for the development of early reading strategies rather difficult (Goswami, 2008, 2011). On the other hand, Bacon et al. (2007) report that when language is used to communicate complex ideas and where reading, visualisation and reasoning are intricately intertwined, the use of verbally embedded imagery may actually hinder reasoning in dyslexics but not in otherwise average readers!

In summary, the notion of dyslexic individuals exhibiting relative strengths in spatial skills is inconsistent and results appear to be partially dependent on the specific method of assessment used. In this area of research, sample sizes are usually small due to the relatively low numbers of children with dyslexia, the complexity of the assessment and scoring procedures. In spite of excellent design, some studies lack the necessary power to identify subtle differences between dyslexic and non-dyslexic groups of children.

## 4. Method

Researching the possibility of dyslexic learners having enhanced visuospatial ability was the main motivation for this study but this was augmented by the fact that the participants were also bilingual.

### *4.1 Participants*

Twelve year-old boys with a diagnosis of dyslexia made by the Directorate for Educational Services' Specific Learning Difficulties (SpLD) Support Unit were compared to a non-dyslexic matched group on measures of visuospatial awareness. Institutional ethical guidelines were adhered to in the recruitment of the participants for this study. A non-probabilistic sample of young adolescent male participants with dyslexia was recruited anonymously through the local school authority. All had been assessed on English and Maltese reading tests and all selected dyslexic participants scored more than one standard deviation below average. Furthermore, all participants (dyslexic and non-dyslexic) possessed an average or above average IQ as assessed for by Ravens Standard Progressive Matrices. Non-dyslexic participants also needed to score at average (within one standard deviation of the mean) or above average levels on the Maltese reading test and have a good record of achievement at school. All participants attended the second year of state secondary school (Form 2/Year 9) and were between 12 and 13 years old. They were all first language speakers of Maltese.

### *4.2 Matching procedure instruments.*

Paper-and-pencil tests were used because of their ease of use and children's familiarity with the procedure in general. Total assessment time was just over two hours but several days lapsed between the administration of the ability and literacy and the spatial ability tests. Initially 90 dyslexic and non-dyslexic participants were recruited but this number was reduced to 36 through the matching procedure that required similar ability levels and diagnosed dyslexia in both languages. The research group was reduced to 16 and of the comparison group to 20. Suggested sample size in experimental research is 15 (Gall, Gall, & Borg, 2003; Sheskin, 2000) or more (Hattie, 2012) participants in each group to be compared. Hattie (2012) notes that effect size for small samples should be used indicatively.

In Malta, the identification of dyslexia through an English language measure is justifiable since this is the language of instruction and testing in all non-language examinations. However, assessing ability in a Maltese population is challenging (Bartolo & Martinelli, 2007) since to date there are no standardized ability tests for the Maltese population. The decision to administer the RPM was taken with cognizance of the fact that it possesses some loading on spatial reasoning (c.f. DeShon, Chan, & Weissbein, 1995; Lynn, Allik, & Irwing, 2004; Van der Ven & Ellis, 2000) but it is a mainly culture-free, pure measure of *g* (Johanson, Bouchard, Krueger, McGue, & Gottesman, 2004; Mackintosh & Bennett, 2005). Johanson et al. (2004) suggest that the implied influence of spatial ability on Raven's latent referent is small in comparison to the implied influence of reasoning and Raven's Matrices can be assumed to load mainly on fluid intelligence and figural reasoning.

### *4.3 Visuospatial awareness instruments.*

The research and comparison groups were administered the *Spatial Reasoning 12-14* (Smith & Lord, 2002a). This battery comprised five separately timed subtests, each of which was preceded by oral instructions, examples and practice items. The timed sections of the test amounted to 33 minutes and the total administration time was around 45-50 minutes. This test assessed the ability to complete a range of cognitive tasks that involved dealing with shape and space, such as mentally combining and rotating, or imagining how three dimensional shapes would look from different viewpoints (Smith & Lord, 2002b). The subtests in this battery were *Hidden Shapes*, *Sections*, *Jigsaws*, *Wallpaper* and *Right Angles* (Smith & Lord, 2002b).

### *4.4 Statistical procedures.*

The research and the comparison groups' performance on the subsections of the Spatial Reasoning Test were analysed by the Shapiro-Wilk test for normality of distribution and a Q-Q plot generated. An independent samples t-test was used to explore the differences between the research and the comparison group on the subscales that were normally distributed, the *Jigsaws, Wallpaper and Total scores.* The Mann-Whitney U test, was used for the *Sections* and *Right Angles subscales* where the assumption of normality of distribution was not confirmed. Cohen's *d* was used to estimate the effect size of the differences between the groups in terms of practical significance. Effect sizes of .5 are generally considered to be medium and .8 large but caveats abound (Baguley, 2009; Lenth, 2001).

## 5. Results

The matched research and comparison groups of dyslexic and non-dyslexic adolescent boys had a mean age of 12 years 10 months. On the Maltese normed reading test, the research group's standardised score differed significantly from the comparison group's (M = 77.4, SD = 8.4) and (M = 106.7, SD = 9.6), t = 9.6, d.f.=34, $p$<.001). These scores confirmed that the groups consisted of poor and average readers as diagnosed by the Directorate for Educational Services' SpLD Support Unit and are displayed in Table 1. The two groups' ages and RPM scores are presented as background detail.

**Table 1.** Mean Ravens Progressive Matrices and Maltese Reading test scores

| | Age in months | | Ravens Progressive Matrices (raw score) | | Progressive Matrices (percentile) | Maltese Reading (standard score) | |
|---|---|---|---|---|---|---|---|
| **Participants** | **Mean** | ***SD*** | **Mean** | ***SD*** | **Mean** | **Mean** | ***SD*** |
| **Dyslexic (n=16)** | 155 | *3.8* | 42 | *5.8* | 50 | 77 | *8.4* |
| **Non-dyslexic (n=20)** | 154 | *3.7* | 42 | *5.4* | 47 | 107 | *9.6* |

All raw scores on the *Spatial Reasoning 12-14* were transformed into a deviation score with a mean of 100 and a standard deviation of 15 points. Table 2 presents the two groups' performance on the *Spatial Reasoning 12-14* Test together with the effect size for the difference between each pair of scores which in most cases was negligible.

**Table 2.** Spatial Reasoning test scores

| Spatial Reasoning Test | Dyslexic group (n=16) | | Non-dyslexic group (n=20) | | Effect size- Cohen's *d* |
|---|---|---|---|---|---|
| | **Mean** | ***SD*** | **Mean** | ***SD*** | |
| **Hidden Shapes** | 96.0 | *16.4* | 107.6 | *10.2* | -0.85 |
| **Sections** | 100.2 | *14.1* | 101.3 | *17.1* | -0.07 |
| **Jigsaws** | 104.5 | *13.0* | 102.5 | *16.3* | 0.13 |
| **Wallpaper** | 101.4 | *16.0* | 100.6 | *16.9* | 0.04 |
| **Right Angles** | 101.1 | *15.0* | 101.0 | *15.4* | 0.01 |
| **Total** | 99.4 | *14.6* | 104.6 | *15.9* | -0.34 |

A close examination of the Q-Q plot for the total data set suggests that the data are normally distributed as shown in Figure 1.

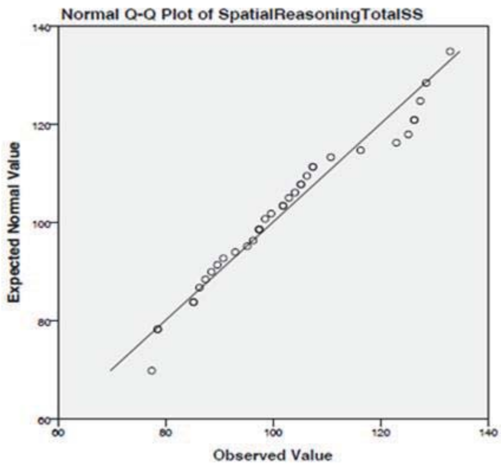


**Figure 1.** Q-Q plot of Spatial Reasoning Total Score

Normality was further assessed by the Shapiro-Wilk Test which is considered to be the best test of normality where small numbers are involved (Zar, 1999). Normality is achieved when the significance level is higher than 0.05 (Coakes & Steed, 2001). Thus for total scores of the *Spatial Reasoning 12-14* the assumption of normality was met (S-W = .949, df = 36, p = .094). This assumption of normality was not established uniformly for all the subtests constituting the battery. In this case, the non-parametric equivalent of the independent samples t-test, the Mann-Whitney U Test was resorted to. The subtests not meeting the assumptions of normality of distribution in the *Spatial Skills Test 12-14* were the *Spatial Reasoning Sections* and *Right Angles* (S-W = .904, df = 36, p = .01; S-W = .936, df = 36, p = .05 respectively).

On the Spatial Reasoning *Hidden Shapes* score there was a significant effect for groups, $t(34)=2.587$, $p=.014$, with the comparison group obtaining a higher score than the research group. Furthermore, Cohen's effect size value (d = .85) suggested a moderately high practical significance. No significant differences were found between the two groups' performance on the *Spatial Reasoning Jigsaws* or the *Spatial Reasoning Wallpaper* subtests with correspondingly low effect size values. The Mann-Whitney U test was conducted for the Spatial Reasoning *Sections* and *Right Angles,* these being indicated as not being normally distributed. The null hypothesis was not rejected for these two measures either, with correspondingly trivial effect size values.

## 6. Discussion

The diversity of findings in the literature ranges from a clear difference in spatial skills (including visuospatial memory), particularly when virtual reality assessments are used (Attree et al., 2009; von Károlyi et al., 2003) to no difference from the rest of the population (Everatt et al., 1999). In spite of a clear difference in the status (dyslexic vs. average readers) of the two groups, this was not associated with significantly different performance on the set of visuospatial tasks administered, except in one instance. This would suggest the consideration of a number of possibilities to explain this result.

In the scenario posited by Everatt et al. (1999) with no inherent differences between dyslexic and average readers on visuospatial tasks, they considered the possibility that the group was still too young to develop a solid visuospatial strategy to deal with the tasks presented. Perhaps with time the participants would come to develop such strategies as suggested by Brunswick et al. (2010) and Everatt (1997).

Bacon et al. (2007) suggest that the difficulty in establishing clear differences between groups is the effect of a mismatch between the research group's natural propensity to excel visuospatially and a culturally determined verbal mediation approach adopted by all participants precluding the research group from maximising its potential. Although plausible, this explanation would require a thorough examination of whether participants applied linguistic reasoning to the visuospatial puzzles using sub-vocal verbal reasoning. Compelling participants to work against strict time limits could force them to rely on their visuospatial skills.

A third possibility is that a clear visuospatial advantage is only evident in real life situations such as map reading and navigating, finding one's way about in unfamiliar surroundings and possibly in three dimensional mechanical and artistic endeavour. In the literature these have been mimicked by computer based tasks in a virtual reality setting as in Attree et al. (2009) and to a lesser extent von Károlyi (2001) but they are still not ecologically authentic.

With specific reference to the comparison group of children participating in this study there is nothing to suggest that good literacy skills are in any way related to better developed spatial skills if one chooses to ignore what is probably the one significant result, *Hidden Shapes*. This finding may be gender linked but this is conjectural. Further research is needed to tap the skills of adolescent girls and boys with dyslexia to explore the issue through a cross-section of schools in Malta while increasing the number of psychological and social constructs they are matched on. Additionally, the use of authentic real life and virtual environment type assessments to explore possible connections between dyslexia and enhanced spatial skills may yet yield some positive results. The variety of results achieved with populations of different ages (Bacon et al, 2007; Everatt. 1997; Everatt et al., 1999; Symonds, 2005; Winner et al., 2001; Wolff & Lundberg, 2002) using varying methodologies (Attree et al., 2009; Everatt. 1997; Everatt et al., 1999; Geschwind & Galaburda, 1987; von Károlyi, 2001) suggests that a clear answer to whether dyslexic individuals actually possess enhanced visuospatial skills remains elusive.

This cross-sectional study suffers from well-known limitations of this type of research and cannot claim to attribute causal relations between dyslexia and visuospatial development (Schulte-Körne et al., 2007). Also, it is difficult to recruit a sufficient number of participants in a small population and this also limits the reliability of findings. However, the careful selection and the matching of dyslexic and non-dyslexic children and the application of the reliable instruments selected for this study provide the opportunity to explore a significant practical and theoretical issue. Notwithstanding, further studies with larger samples and virtual reality procedures are warranted.

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