Visual-motor Integration Skills in Children with Mild Intellectual Disability: A Meta-analysis

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Abstract

Visual-motor integration (VMI) skills, defined as the coordination of fine motor and visual perceptual abilities, are a very good indicator of a child's overall level of functioning. Research has clearly established that children with intellectual disability (ID) have deficits in VMI skills. This paper presents a meta-analytic review of 10 research studies involving 652 children with mild ID for which a VMI skills assessment was also available. We measured the standardized mean difference(Hedges' g) between scores on VMI testsof these children with mild ID and either typically developing children's VMI test scores in these studies or normative mean values on VMI tests used by the studies.While mild ID is defined in part by intelligence scores that are 2-3 standard deviations below those of typically developing children, the standardized mean differenceof VMI differences between typically developing children and children with mild ID in this meta-analysiswas1.75 (95%CI: 1.11-2.38).Thus, the intellectual and adaptive skill deficits of children with mild ID may be greater(perhaps especially due to their abstract and conceptual reasoning deficits) than their relative VMI deficits. We discuss the possible meaning of this relative VMI strength among children with mild ID and suggest that their strongerVMI skills may be a target for intensive academic interventionsas a means of attenuatingproblems in adaptive functioning.

Key words: visual-motor integration, intellectual disability, children with mild intellectual disability, meta-analysis

Introduction

Intellectual disability (ID) is characterized by limitations in both intellectual functioning and adaptive behavior, and, by definition, it is manifested before age18 (American Psychiatric Association, 2013; Schalock et al., 2010). The presence of significant deficits in intellectual and adaptive functioning havedefinedID for more than 50 years (Schalock, Luckasson, &Shogren, 2007). According to the Diagnostic and Statistical Manual of Mental disorders-5th edition(DSM-5; American Psychiatric Association, 2013), deficits in intellectual functions involve deficits in reasoning, problem solving, planning, abstract thinking and practical understanding. In addition, critical components ofthe ID definition include problems in verbal comprehension, working memory, perceptual reasoning and cognitive efficacy (American Psychiatric Association, 2013). For example, prior research has found that people with ID havedeficits in communication(Abbeduto, Weissman, & Short-Meyerson, 1999; Pinborough-Zimmerman et al., 2007), working memory(Van der Molen, Van Luit, Jongmans, & Van der Molen,2007; Schuchardt, Gebhardt, &Mäehler, 2010), perceptual performance (Woodhouse et al., 1996; Di Blasi, Elia, Buono, Ramakers, & Di Nuovo, 2007), and fine and gross motor skills(Vuijk, Hartman, Scherder, &Visscher, 2010).The prevalence of ID is dependent on many factors such as social status (Larson et al., 2001), age (Maulik, Mascerenhas, Mathers, Dua, &Saxena, 2011) and gender (Lai, Tseng, Hou, &Guo, 2012). A meta-analysis of ID prevalence studies published between 1980 and 2009 reported that the highest estimates of ID were in low and middle income countries (Maulik et al., 2011). The most frequently reported prevalence of ID is around 1% (McKenzie, Milton, Smith, &Ouellette-Kuntz, 2016), but it can be up to 3% of the general population (Heikura et al., 2003). With respectseverity, ID is classified into four categories: mild, moderate, severe and profound. While these severity levels were formerly based mainly on intelligence test scores, the DSM-5 now defines severity levels by adaptive functioning that is more closely related to the level of required support. Around 85% of all persons with ID belong to the category of mild IDfor which there are challenges in conceptual, social, and practical life skills and a need for intermittent, support in certain life activities (Boat & Wu, 2015).

Research involvingfine motor skills of persons with ID is particularly important as these skill deficits relate to both cognitive and adaptive defining criteria; they are prerequisites for many everyday activities (Memisevic&Hadzic, 2013). The relationship between fine motor skills and adaptive behavior has been studied widely, especially in children with developmental disabilities. For example, research to date has shown that fine motor skills are significant predictors of adaptive behavior in children with autism spectrum disorders(Jasmin et al., 2009; MacDonald, Lord, & Ulrich, 2013) and of crucial importance to children's health and overall development (Obrusnikova& Cavalier, 2017). Other studies have shown that fine motor skills contribute to kindergarten achievement (Cameron et al., 2012). In addition, fine motor skills continue to exert an influence on academic skills in elementary school and are correlated with academic outcomes in math, reading, writing and spelling (Kulp, 1999;Suggate, Heidrun, & Fischer, 2017).

The interactive coordination of both fine motor and visual perceptual skills constitutes visual-motor integration (VMI) (Beery & Beery, 2010).VMIskills are a very good indicator of a child's overall level of functioning, as they correlate significantly with academic achievement and intellectual functioning (Duijff et al., 2012; Graf & Hinton, 1997; Kulp, 1999). However, the exact nature of the relationship between VMI and intellectual functioning is not clear. Some prior studies used measures of intellectual functioning to predict VMI skills. For example, Wuang, Wang, Huang, & Su (2008) found that processing speed, verbal comprehension and perceptual organization predicted VMI scores, and others have shown that Performance IQ scores within the Wechsler intelligence scales wasmore strongly correlated with VMI scores than were Verbal IQ and Full Scale IQ scores within the Wechsler's scales (Graf & Hinton, 1997; DiBlasi et al.,2007).

Eye-hand coordination is a significant component of VMI, and there is some overlap between eye-hand coordination and VMI.Eye-hand coordination is a skill in which both visual (eyes) and motor (hands) processes are efficiently applied together to perform everyday activities such as dressing, doing chores, and handwriting (Shin, Song, &Hwangbo,2015).Handwriting has been studied extensively in relation to VMI skills, and research has consistently identified strong correlations between VMI and handwriting skills (Pfeiffer et al., 2015).

VMI skills are dependent on intact visual-perception, fine motor coordination, motor inhibition and sustained attention (Schultz et al., 1998). VMI assessment constitutes an essential part of an individual child'spsycho-educational and/or neuropsychological assessment for school or rehabilitative planning (Demski, Carone, Burns, & Sellers, 2000). Although related to intellectual functioning, VMI deficits can be present in the absence of intellectual deficits. Given this independence from intellectual functioning and due to their complex structure, VMI skills have been studied widely in clinical populationsin efforts to localize brain dysfunction and more precisely describe and plan fora VMI deficit. For example, Mattison, McIntyre, Brown, & Murray (1986) studied children with a specific learning disability (with intelligence scores ranging from 85-115) who had VMI deficits that were defined by problems in the integration of visual-perceptive and motor-coordinative components but that were notdue to specific problems with either the visual or motor system.Others have examined VMI deficits in specific clinical populations. These studies have included Schultz et al.'s (1998) finding that children with Tourette syndrome hadVMI skillsthat wereone standard deviation below the levels of typically developing children, and Sutton et al.'s (2011) findingthat children with traumatic brain injury (TBI) had scores that were 1.3 standard deviations below those of typically developing children. Ercan, Yilmaz, Tas,& Arai (2016) found that a group of children with speech-sound problems had significant deficits in VMI skills of1.3 standard deviationsbelow a control group of children without speech-sound problems. Replications of these studies are needed before assuming that these findings generalizeto other samples of children with these various clinical disorders. A large meta-analysis by Geldof, Van Wassenaer, De Kieviet, Kok, andOosterlaan(2012) showed that children born preterm and children with low birth weight hadmedium to large effect size deficits in VMI, relative to typically developing children.When VMI has been studied in persons with ID (e.g., Muñoz-Ruata, Caro-Martínez, Martinez Perez, & Borja, 2010), there have been consistent findings of VMI deficits, thoughtheir extent and nature in this population remains unclear.

Given the importance of a relationship between VMI skills and adaptive behavior and intellectual functioning, we sought to better understand the nature and extent of VMI deficits in children with mild ID compared to typically developing children. As the defining criteria for mild ID are deficits in intellectual and adaptive functioning in the range of 2-3 standard deviations below the general population mean, we sought to determine whether VMI deficits for this group would show the same pattern relative to typically developing children. We employed a meta-analysis of studies of children with mild ID who had also been administered VMI testing to determine whether the effect size differences between children with mild ID and typically developing children would correspond to the expected 2-3 standard deviation deficits in intellectual and adaptive functioning that children with mild ID experience in relation to typically developing children.

Method

Literature search

For this review, we searched the literature for studies in which VMI skills were assessed with well researched and standardized tools (see further description below) in children (aged 0-18 years of age) with mild ID (see definition below). Studies containing the terms “visual motor integration skills”, “perceptual motor skills” and “intellectual disability” ("mental retardation") were searched in the SCOPUS, PubMed and Web of Science databases. We then further examined referenced articles mentioned inthe initially selected articles to locate any additional relevant studies we might have missed.

Study selection

Each of the two authors of this paper conducted independent searches in this manner to ensure that no study was missed. Any discrepancies were identified and discussed, with both authors in agreement that our final selections were a comprehensive set of relevant research articles to be reviewed.Study inclusion criteria depended upon the following definitions and specific guidelines:

1. For a study to be selected as one with children with mild ID one of two definitions of mild ID had to have been met:(a) the study’sauthorsspecifically stated that their participants were children with mild ID in accordance with DSM-5 criteria; or (b) the study provided sufficient participant characteristics detail for us to inspect it and

assure ourselves that children considered to be of mild ID had intelligence testscoresthat were 2-3standard deviations (SD) below the general population mean for typically developing children, including a margin for measurement error such that onintelligence tests with means of 100 and SDs of 15, children's scores ranged between 50-75. While the DSM-5 suggests that the severity level of ID is determined from adaptive functioning rather thanfrom intelligence test scores, most authors reported only intelligence test scores.

Intelligence tests used in the studies. Different measures of intellectual functioning were used in the selected studies. Eight studies used various forms of the Wechsler Intelligence Scales for Children (WISC, 1949 = one study; WISC-III, 1991 = twostudies; WISC-R, 1986 = twostudies; WISC-R, 2002; WISC-IV, 2004 = one study]. In one study authors employed the Wechsler Preschool and Primary Scale of intelligence- Revised (WPPSI-R, Van Der Steene & Bos, 1997). One study employed both, the Stanford-Binet Intelligence Scale (SBIS, Bozzo & Mansueto Zecca, 1993) and WISC-R test. Finally, one study used the Kaufman Brief Intelligence Test (K-BIT, Kaufman & Kaufman, 1990). In one study, the author did not report the instrument used for IQ assessment (Table 1). In eight studies the authors provided data about the mean intelligence test scores of the participants (ranging from 57.5 to 73). In a study by Memisevic and Sinanovic (2012), the authors stated that mild ID was determined through the Revised Wechsler Scale for Intellectual Assessment (REVISK; Biro, 1997) but did not provide mean intelligence test score values. Also, in a study by Condel (1963), the author did not report IQ scores of the participants but described them as "educable"(referring to *Educable Mentally Retarded*) which was the term used to describe children with mild ID at the time this study was published. In one study, the authors defined mild ID on the basis of both defining criteria of intelligence and adaptive behavior deficits (Gresham, MacMillan, & Bocian, 1996). The intelligence tests used in these studies all have very good psychometric properties.

The reliability coefficient for the first version of WISC was between .86 and .95 (Wechsler, 1949). This high reliability has remained stable in newer versions of the test, and the factor scores within the test have generally shown equivalent reliability to their analogous intelligence quotients (Rossini & Kowalski, 1986). Studies have shown that the WISC-R has moderate stability over a 3-year testing interval for persons with learning disabilities (Anderson, Cronin, & Kazmierski, 1989). The WPPSI has a high reliability ranging from .89 to .95 (Wechsler, 1989). Similarly, the WISC-III has a reliability ranging from moderate to excellent, (.61 to .92) and also has excellent consistency (.80 to .97; Wechsler, 1991). The WISC-IV also has high reliability coefficients (.88 to .97). Adaptation and standardization of the WISC-R for the Serbian population resulted in the REVISK test that has subtests to test correlations between .80 to .93 and subtest inter-correlations that range from .58 to .89. Composite internal consistency reliability fortheK-BIT (Kaufman & Kaufman, 1990) was .93, and this test has a composite test-retest correlation coefficient mean of .94 (Parker, 1993). High test-retest reliability is also present for the SBIS, ranging from .87 to .97 (Dacey, Nelson, & Stoeckel, 1999; Thorndike, Hagen, & Sattler, 1986).Studies have shown that these various intelligence test measures correlate highly between each other, which has been seen as evidence of good validity. For example, the WISC – WISC-R correlation was .89, WISC-R – SBIS correlations have ranged from .51 to .77,the WISC IV– K-BIT correlation was .88-.89,and the K-BIT– WISC III correlation was .71 (Canivez, 1995; Jazayeri & Poorshahbaz, 2009; Kaufman & Kaufman, 2004; Kezer & Arik, 2012).

2. For a study to be selected for this review as one in which VMI skills had been assessed well, the study had to include a standardized paper and pencil test commonly used for VMI assessment such as the Beery VMI test (Beery & Beery, 2010) or the Bender Visual Motor Gestalt Test (Bender, 1938). Thesecommon measures for assessing VMI in children require children to copy increasingly complex geometric forms with paper and pencil; they have well established norms with typically developing children. Thus, for this analysis we only evaluatedVMI tests as outcome measures when those tests involved copying of shapes and had established performance norms for children of various ages, separated by gender. Besides being comparable in its construct equivalence, most of these tests are culture-free, making them ideal for the purpose of this research.

VMI measures used in these studies. The Bender Visual Motor Gestalt Test (BVMGT; Bender, 1938) was used in three studies. The Beery Test of Visual Motor Integration (VMI; Beery, 1997) was used in five studies. The Wide Range Assessment of Visual Motor Abilities (WRAVMA; Adams & Sheslow, 1995) was used in one study, and theACADIA test of developmental abilities (Novosel, 1995) was used in one study.

Regarding psychometric properties reported for these tests, interrater reliability for the BVMGT (Gresham et al., 1996) ranged from .76 to .99, and test-retest reliability ranged from .50 to .90. As for the Beery VMI (Beery &Beery, 2010), the measure ofinternal consistency, Cronbach Alpha, has been found to be .89, test-retest reliability .88 and interrater reliability .93. Also the WRAVMA (Adams & Sheslow, 1995) has very good psychometric properties, withinternal consistency, Cronbach alpha of .75, test-retest reliability of .86 and interrater reliability of .96. For the ACADIA test (Radovanovic, 2013) the internal consistency is .70 and reliability .90. From this overview, it is obvious that all these tests have satisfactory psychometric properties.

Validity measures for these tests were mostly established by demonstrating high positive correlations between these tests and between the tests and children's academic outcomes. For example, the Beery test has moderate, statistically significant, correlations with academic outcomes ranging from .27 to .50 (Klein, 1978). Similarly, a statistically significant correlation of .41 was reported between theACADIA test and school success (Novosel & Nikolic, 1991). The Bender-Gestalt test was also found to be significantly correlated with school success (Brito & Santos, 1996). Beery VMI significantly correlated with WRAVMA, with correlations ranging from .52 to .76 (Adams & Sheslow, 1995; Beery et al., 1997).

3. For a study to be selected for this review as one containing a control group of typically developing children, one of two definitions of typically developing children had to have been met: (a) the study's authors specifically stated that some participants were typically developing children; or (b) VMI scores provided from the mild ID group had to have been derived from a VMI test that permitted direct comparison of a study child's VMI score to the test's normative sample of same aged typically developing children.

4. All studies selected were written in English and published in peer reviewed journals in the period 1960- present.

Studieswereexcluded according to the following criteria:

1. Children with mild ID also carried a comorbid diagnosis of Autism Spectrum Disorder and/or Cerebral Palsy;
2. Research was presented in the form of non-original articles, reviews, letters, or case studies, rather than peer-reviewed research.
3. Authorsutilized different visual perceptual or fine motor measures than visual-motor integration tests (e.g., Grooved Pegboard, Visual Form Recognition, etc.);

The flowchart for study selectionis shown in Figure 1.

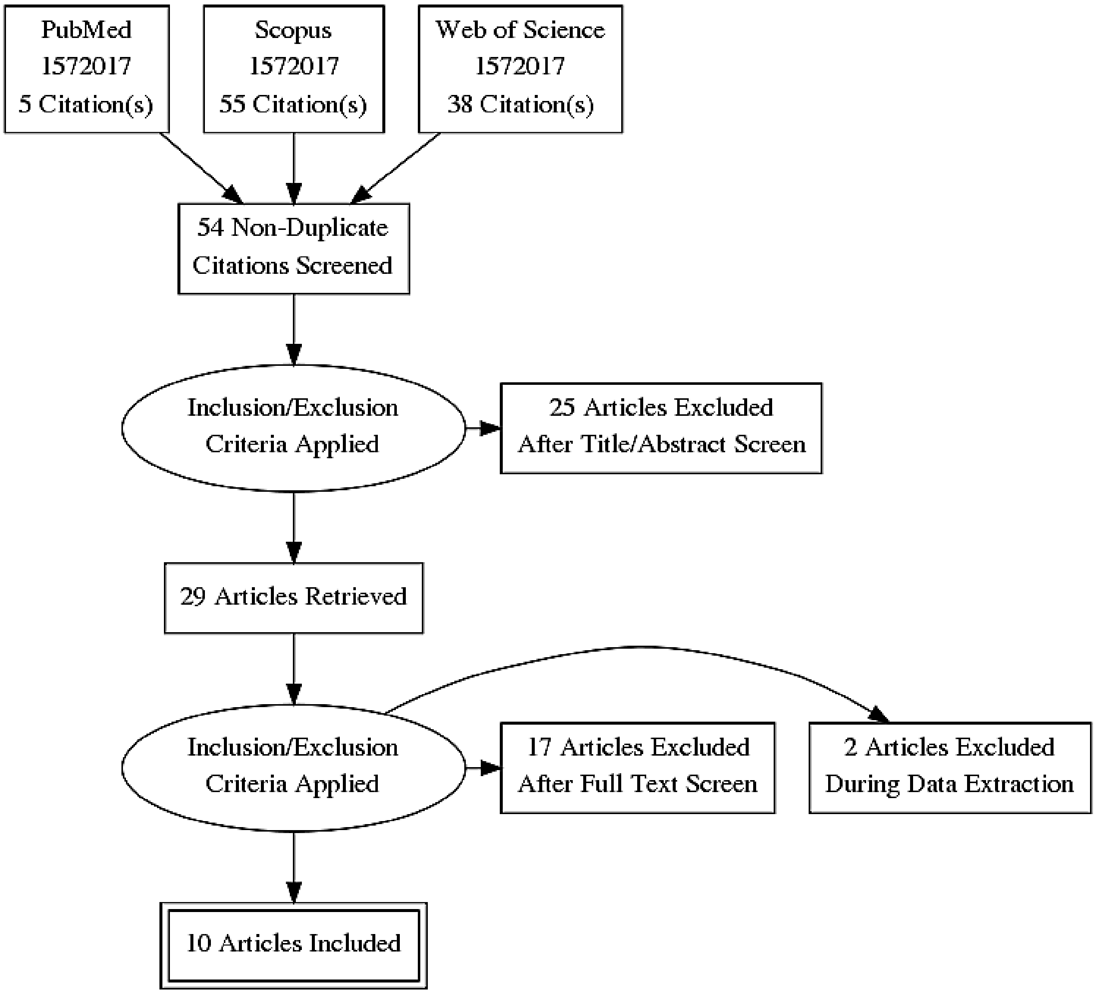

Figure 1. Selection of studies for meta-analysis on the VMI in children with mild ID

Statistical analysis

A main presumption in meta-analysis is that participant scores from different studies are comparable through their standardized mean difference (Nugent, 2017). All means and standard deviations (SD) of VMI scores for children with mild ID were obtained from the analyzedstudies.Means and SDs of VMI scores for children without ID were obtained from either the published studies (six studies) or the normative standardized test sample (four studies). A standardized mean difference (Hedges' g effect size) was calculated to assess the magnitude of VMI difference scores between children with mild ID and typically developing children. In addition,for VMI scores within these 10 studies, we also performed a Q test and an I^2 test of heterogeneity.

Results

Participant Characteristics in the 10 Selected Studies

Aggregated demographic data for participants in studies selected for this meta-analysis are summarized in Table 1. From studies that met inclusion/exclusion criteria as specified in the Method section of this paper, the total or aggregated participant sample was 652 children with mild ID. As can be seen from the Table 1, we identified 10 studies assessing VMI in children with mild ID aged 0-18 years. Six studies included a control group of children without ID, whilefour studies had no control group of typically developing children.In the four studies without a control group, we compared actual VMI test scores of children with mild ID toscores ofsame-aged children in the normative sample

for the particular VMI test.

Table 1. Demographic Data of Participants From Selected Studies.

Author(s)	Year published	Number of participants with mild ID	Mean IQ	IQ measures	Mean age (years)	Outcome measures	Country
Condell	1963	28	–	–	M =11.47	Bender Visual Motor Gestalt Test (Bender-Gestalt, 1938)	United States
Simensen	1974	100	66.1	WISC	M = 12.42	Bender Visual Motor Gestalt Test (Bender-Gestalt, 1938)	United States
Gresham, MacMillan, and	1996	45	67.86	WISC-III (Wechsler, 1991)	M = 8.92	Bender Visual Motor Gestalt	United States

Bocian						Test (Bender-Gestalt, 1938)	
Vicari, Mantovan, Addona, Costanzo, Verucci, and Menghini	2012	12	63.7	Stanford-Binet Intelligence Scale (Bozzo & Mansueto Zecca, 1993) and the Wisc-R (Wechsler, 1986)	M = 11.5	The Developmental Test of Visual-Motor Integration (VMI; Beery et al., 1997)	Italy
Dykens	2002	21	57.5	Kaufman Brief Intelligence Test (KBIT; Kaufman & Kaufman, 1990)	M=14.10	The Developmental Test of Visual-Motor Integration (VMI; Beery et al., 1997)	United States
Howley, Prasad, Pender, and Murphy	2012	31	70.12	WISC-IV (Wechsler, 2004)	M=11.4	The Wide Range Assessment of Visual Motor Abilities (WRAVMA; Adams & Sheslow, 1995)	Ireland
Duijff, Klaassen, Beemer, de Veye, Vorstman, and Sinnema,	2012	65	73.0	Dutch version of the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R; Van der Steene & Bos, 1997)	M =5.6	Beery-Buktenica Developmental Test of Visual-Motor Integration Short Form (VMI; Beery & Beery, 2004)	Netherlands
Memisevic and Sinanovic	2012	42	–	REVISK (Biro, 1997)	M = 11.3	The Acadia test (Novosel, 1995)	Bosnia and Herzegovina
Wuang, Wang, Huang, and Su	2008	233	57.91	WISC-III (Wechsler, 1991)	M = 7.55	The Developmental Test of Visual-Motor Integration (VMI; Beery et al., 1997)	Taiwan
Lo, Collin, and Hokken-Koelega	2015	75	62	WISC-R (Wechsler, 2002)	M =11.8	The Beery-VMI (Beery & Beery, 2004)	Netherlands

IQ = intelligence quotient; ID = intellectual disability; WISC =Wechsler intelligence scales for children.

Further details regarding mild ID and participants' gender in selected studies

Six studies offered information about the etiology of the ID of the study's participants. In two of these, participant children with mild ID were said to have Prader-Willi syndrome (Dykens, 2002; Lo, Collin, &Hokken-Koelega, 2015), in three the participants were said to have 22q11.2 deletion syndrome (Duijff et al., 2012; Howley, Prasad, Pender, & Murphy, 2012; Vicari et al., 2012), and in the participants had heterogeneous etiologies for their IDs (Memisevic & Sinanovic, 2012). The remaining four studies made no mention of ID etiology (Condel, 1963; Simensen, 1974; Gresham et al., 1996; Wuang et al., 2008). Since the presumptive etiology for all children with mild ID is congenital, rather than acquired, all 10 studies (the six in which children had Prader-Willi syndrome, 22q11.2 deletion syndrome, or heterogeneous etiology and the four in which further etiologies were not described) are all presumed to have included participants with mild congenital ID.

As for the participants' gender, eight studies gave information about participants gender distribution, covering a total of 598 children (330 or 55% boys; and 268 or 45 % girls). Two studies did not contain gender information (Memisevic & Sinanovic, 2012; Vicari et al., 2012). For the Memisevic and Sinanovic (2012) study, we recovered this data (24 boys and 18 girls with mild ID), creating a new meta-analysis sample that totaled 354 boys (55%) and 286 girls (45%), leaving only12 children among these combined studies for which there was no available gender data. According to the *one proportion test*, the difference in the proportion of boys and girls was not the same in this meta-analysis, z=2.5; p= .01 (95% CI of observed proportion of boys 51.1% to 59%). The higher proportion of boys would remain statistically significant even if all 12 children from the Vicari et al. (2012) study were girls (p=.04; 95% CI 50.1%-57.9%).This gender imbalance is not surprising, asmales are more susceptible to a variety of neurodevelopmental risk factors associated with ID (Di Renzo, Rosati, Sarti, Cruciani, & Cutuli, 2007), and certain cultural factors enable easier identification of ID in males (McDonald, Keys, & Balcazar, 2007).

VMI Differences between Children with Mild ID and Typically Developing Children

We calculated the standardized mean difference (Hedges'*g* effect size) to assess the magnitude of VMI difference scores between childrenwith mildID and typically developing children. Hedges's *g* is a variation of Cohen's *d* effect size, and itis adjusted for biases in a small sample size (Hedges & Olkin, 1985). As the effect size measures of Hedges' *g* and Cohen's *d* are calculated in a similar way, we used effect size interpretation guidelines postulated by Cohen (1988) to classify standardized mean differences (0.2- small ES, 0.5 moderate ES and 0.8 large ES). The forest plot of effect sizes is presented in Figure 2.

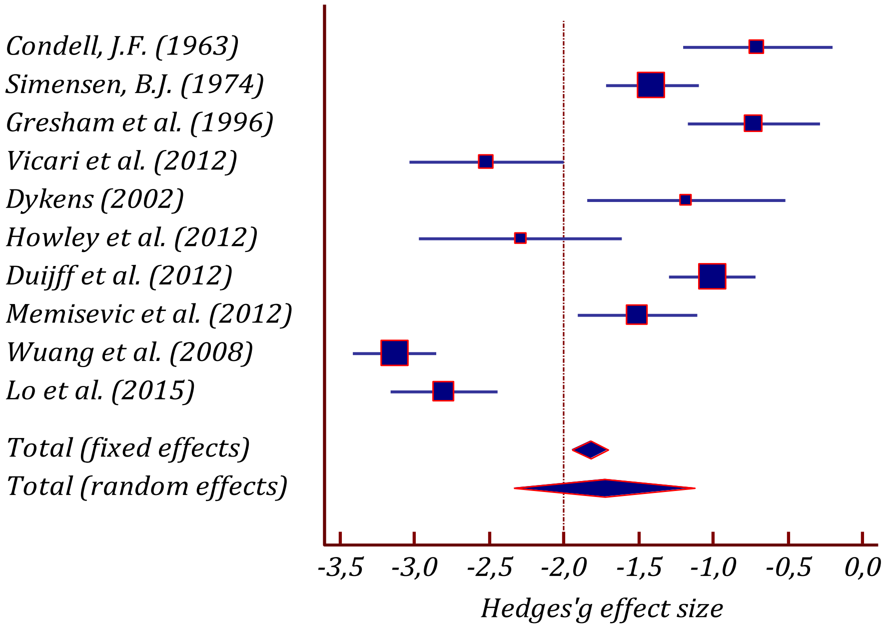

Figure 2. Forest plot of each reviewed study's standardized mean difference between VMI test scores, when comparing children with mild ID to typically developing children.

Note. Vertical line drawn at 2 SD below the control group.

We also performed a Q test and anI^2 testof heterogeneity regardingVMI scores within these ten studies. Both tests confirmed that the studies were very heterogeneous (Q=183,5, df=9, p<.0001; I^2=95.1., 95% CI 92.7-96.7). The mean value of standardized mean difference for the fixed effect was 1.86 (95%CI: 1.73-2.0). As the studies were largely heterogeneous, better summary of standardized mean difference is the measure of random effects. The mean value of total standardized mean difference for random effects was 1.75 (95%CI: 1.11-2.38). The standardized mean difference for each study in VMI test scores between children with ID and typically developing children is shown in Table 2.

Table 2. Standardized Mean Difference on VMI Test When Comparing Children With Mild ID to Typically Developing Children.

Study	N1	N2	Total	Mean (SD)[a]	Mean (SD)[b]	SMD	SE	95% CI
Condell, J. F. (1963)	28	41	69	3.6 (2.5)	6.1 (4.2)	0.70	0.25	[1.20, 0.20]
Simensen, B. J. (1974)	100	100	200	4.2 (2.1)	7.7 (2.8)	1.41	0.16	[1.72, 1.10]
Gresham et al. (1996)	45	40	85	96 (12)	107.5 (19.1)	0.72	0.22	[1.17, 0.28]
Vicari et al. (2012)	12	12	24	14.5 (3.7)	22.2 (2.7)	2.29	0.51	[3.36, 1.23]
Dykens (2002)	21	21	42	12.7 (4.6)	18.5 (5)	1.18	0.33	[1.85, 0.52]
Howley et al. (2012)	31	26	57	74.9 (11.4)	102.8 (12.7)	2.29	0.34	[2.97, 1.61]
Duijff et al. (2012)	65	65[c]	130	86.2 (8.4)	100 (15)	1.13	0.19	[1.50, 0.76]
Memisevic et al. (2012)	42	42[c]	84	36.1 (6.8)	50 (10)	1.61	0.25	[2.10, 1.11]
Wuang et al. (2008)	233	233[c]	466	64.2 (6.9)	100 (15)	3.06	0.14	[3.32, 2.79]
Lo et al. (2015)	75	75[c]	150	62.0 (8)	100 (15)	3.14	0.24	[3.63, 2.66]
Total (fixed effects)	652	655	1307			1.86	0.07	[2.0, 1.73]
Total (random effects)	652	655	1307			1.75	0.32	[2.38, 1.11]

Note. SMD = standardized mean difference; SE = standard error; N1 = children with intellectual disability; N2 = children without intellectual disability.

[a] Means and SD on VMI tests for children with ID.

[b] Means and SD on VMI tests for typically developing children.

[c] Studies did not have a control group of children without intellectual disability, thus, as a comparison we used same number of children without intellectual disability from normative sample.

Discussion

As previously established in the literature on VMI in children with ID,we found significantlylower scoreson VMItests among the 652 participants with mild ID, relative to typically developing children. As can be seen in our meta-analysis, the 10 studies we included revealed very heterogeneous degrees of association between ID and VMI skills for these participants. However, the general trend of these studies consistentlyshowed that the VMI performance of children with mild ID was lower than that of typically developing children, andthrough a closer analysis we gained a clearer picture of the extent of these children’s VMI skill deficits relative to typically developing children.

More specifically, through this meta-analysis of studies published over a period of more than fifty years, the standardized mean difference of lower VMI scores of children with mildIDversus their typically developing age peers was 1.75 or 1.11-2.38 standard deviations. Thus, the VMI skill difference between children with mild ID and their typically developing peers was less than the 2-3 standard deviation difference that separated the children with ID in their intellectual and adaptive functioning from typically developing peers. Thus, VMI skills represented an apparent strength relative to the defining intellectual and adaptive behavior deficits of children with mild ID, perhaps with positive implications for targeted teaching toward these strengths in the hope of better preparing these children for further maturational challenges.

The results of this meta-analysis have important implications for education and rehabilitation, especially sinceVMI skills have been found to be important for school success and adjustment (Dankert, Davies, & Gavin, 2003). In fact, the main purpose of VMI testing is to help predict school learning problems (Brannigan & Decker, 2006). In some cases, VMI scores maybe even better suited for this purpose than the intelligence quotient (Baghurst et al., 1995). For example, Baghurst et al. (1995) found that the Beery VMI test was better than other cognitive tests for detecting the effects of lead poisoning on child development. To date many studies have shown that VMI skills are susceptible to structured training, especially to improve perceptual and motor skills duringthe preschool period (Tzuriel & Eiboshitz, 1992). As VMI is dependent on fine motor coordination, visual perception and sustained attention, improvement in any of these areas would likely benefit children generally.Several studies have demonstrated significant and meaningful fine motor skills training benefits for both children and adults with ID (Sood, Ahmad, &Chavan, 2017; Azar, McKeen, Carr, Sutherland, & Horton, 2016).Visual perception skills can also be trained (Kurylo, Waxman, Kidron, & Silverstein, 2017). Especially effective and promising are computer based games/programs aimed at improving children's perceptual and attention skills (Boot, Kramer, Simons, Fabiani, & Gratton, 2008; Green, Gorman, & Bavelier, 2016; Gozli, Bavelier, & Pratt, 2014). Studies have demonstrated that playing certain types of action video-games can have a positive impact on visual-motor control (Li, Chen, & Chen, 2016). Given these data on the relationship between VMI and adaptive behavior, we can be hopeful that VMI training might positively impact adaptive behavior.This in turn will lead to better everyday functioning of children with mild ID.Future studies are suggested in order to specifically address how VMI improvements in this population at a young age might affect intellectual and adaptive functioning over time.

There are some important limitations to this research. First, findings within our study of children with mild ID should not be presumed to apply to adults with mild ID. Further research with adults is clearly needed, and it would be interesting to examine age effects as a covariate in the relation between VMI and intellectual and adaptive functioning since some past research has shown that VMI skills generally decline with older age (Kim, Park, Byun, Park, & Kim, 2014).Secondly, apart from this meta-analytic approach, new research with very large groups of children with mild ID and typically developing children might directly address whether VMI scores represent splinter strengths among general impairments and have particular deviance from measures of adaptive and general intellectual capabilities. It is also important to note that the sample of children with mild ID in this meta-analysis was heterogeneous in relation to the etiology of ID. It is possible that there might be etiology-specific differences in VMI skills among children with mildID, and this question also warrants further investigation. Finally, our study's limitations include those of any meta-analysis, such as the possibility of a biased study selection. Meta-analyses examining group differences on selected variables should not be as prone to publication bias as studies examining intervention effects, but a more significant and surprising limitation, given the extensive period of time over which our literature search spanned, was that we were only able to locate10 studies that met our inclusion/exclusion criteria. Our search was limited to articles published in English because we lacked there sources to translate articles written in other languages. Furthermore, some studiesthatmight have otherwise met our inclusioncriteria had to be omitteddue to lackof needed information (commonlydue to authors having failed to fully reporttheir participants' test score means and standard deviations). Also, despite our efforts to make this review comprehensive, some studies may have been missed, due to their publication in journals outside of the databaseswe examined. Finally, due to the small number of studies we were able to analyze, some possibly relevant moderating variables could not be studied, including participant age of diagnosis and related access to special education. Apart from these limitations, however, our study has some important strengths. To the best of our knowledge this is thefirst meta-analysisof VMI skills and their relative magnitude in relation to intelligence and adaptive ability levels in children withmild ID.

Our study has both theoretical and practical implications. From a theoretical perspective, it provides us with a better picture of the extent of VMI deficits in children with mild ID, permitting greater insight regarding the ID construct. These data suggest a future value to a more routine use of VMI testing to complement other data gathering regarding the ability levels of children suspected of mild ID (Duijff et al., 2012). Additionally, VMI assessment may be useful for organizing programs that stimulate cognitive development (Okkerse, Beemer, Mellenbergh, Wolters, & Heineman-de Boer, 2005), serving, in turn, as a basis for more effectively allocating support services to children with ID. Some research seems to support our claim regarding discriminative properties of VMI tests (Wuang & Su, 2009). In practice, our study can serve as a basis for curriculum modification for children with mild ID. Previous studies have found a strong link between VMI and handwriting skills (Daly, Kelley, & Krauss, 2003).Additional training in VMI skills may result in better writing readiness and, perhaps through this improvement, better overall academic outcomes. Training in VMI skills may also improve other aspects of daily living skills for children with mild ID, justas it has for typically developing children (Jasmin et al., 2009). We hope that this study will spark an increased research interest in this important skill set.

Importantly, however, as a caveat to the foregoing hopes, the interpretation or meaning of our findings should be approached cautiously, pending further research. It is not yet clear whether the higher VMI scores (relative to general intellectual functioning)that we observed may reflect a genuine ability difference in visual-motor integration for children with mild ID or whether test measures of VMI skills may represent less challenging or less psychometrically robustmeasures, relative to test measures of general intelligence. Since tests of VMI abilities are narrower in scope, shorter in duration, and less closely associated with higher order cortical abstract reasoning, novel problem solving, and conceptualization skills, it is possible that these relatively higher VMI scores represent afailure of VMI tests, relative to intellectual tests, to accurately measure and predictlater functioning in children with mild ID, as they age into life requirements for these higher cortical abilities.This possibility is partially supported byother research findings showing that VMI skills (or the test scores that represent these skills) generally decline with age (Kim et al., 2014).

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