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RESEARCH ARTICLE

Evaluating fine perceptual-motor skills in children with mild intellectual disability

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Abstract: Over the years, several studies have indicated that delay in perceptual-motor development and impaired motor organization is strongly associated with the level of cognitive functioning and performance in children. The aim of the present research study was to assess the fine perceptual-motor skills of children with mild intellectual disability 7-9-years-old and the comparison of their performance with two groups of typically developing children with the same chronological and a corresponding mental age. Our research sample consisted of 129 children between the ages of four and nine years whilst the experimental group had a total of 43 children (7-9-years-old) with mild intellectual disability. As an assessment tool of fine perceptual-motor skills we used a battery of tasks constructed in accordance with other commonly used standardized tests that measure psychomotor abilities. Furthermore, several comparisons were carried out in order to investigate our experimental hypotheses. Overall, our results revealed that children with mild intellectual disability scored lower in the tasks compared to typically developing children of equal chronological age but significantly higher than the group of typically developing children of the same mental age (preschoolers). The results of the psychometric properties of our designed tasks (reliability, validity) verify the high-quality psychometric characteristics of the designed tool.

Keywords: fine perceptual-motor skills, mild intellectual disability, cognitive development, perceptual-motor performance, typically developing children

1 Introduction

Children with mild intellectual disability (ID) exhibit sensory and perceptual-motor difficulties that significantly impact their everyday performance (Aharoni, 2005; Wuang et al., 2009). The view that the average performance of motor skill development of children with ID is lower when compared to the one observed in typically developing children of the same age group is supported in several studies. (Houwen et al., 2016; Memisevic & Djordjevic, 2018; Rintala & Loovis, 2013; Kartasidou, 2004; Vuijk et al., 2010).

As stated by Goutziamani-Sotiriadi (1993), there is a strong correlation between motor development delay, impaired motor organization and the level of performance of mental functioning. The research of Smits-Engelsman & Hill (2012) proved that individuals with a lower measured intellectual quotient (IQ) more often showed poorer motor performance than those with a higher measured IQ.

Therefore, there is a high likelihood that children with ID will demonstrate motor performance deficits (Aggelopoulou-Sakadami, 1999; Farrell, 2003; Polychronopoulou, 2004; Wuang et al., 2012). The severity of the delay determines the dysfunction of motor skills (Beirne-Smith et al., 2006; Houwen et al., 2016; Jeoung, 2018; Vuijk et al., 2010), as well as the variability of motor performance.

Both fine and gross motor development are strongly associated with cognitive functions in children diagnosed with or without intellectual disability (Houwen et al., 2016; Wuang et al., 2008). It is true that motor and intellectual domains in children without ID are largely independent (Jenni et al., 2013).

In addition, it is noteworthy that children with ID display developmental delays in basic motor skills and movement patterns such as walking, running, jumping as well as many other manipulative skills that precede to the acquisition of motor skills (Garcia-Nonell et al., 2006).

The motor development of children with intellectual disability from infancy onwards progresses at a slower pace compared to that of typically developing children of the same chronological age. Parents, who are concerned with the development of their children, could detect a delay in the motor skills' acquisition before realizing a delay in cognitive domain. Parent's report is a useful measurement of children's motor skill performance (Kennedy et al., 2012).

Although sensory integrative functions are only mildly impaired, both verbal comprehension and processing speed indexes, are significant predictors of fine motor function. Many prominent researchers (Elliott & Bunn, 2004; Giagazoglou et al., 2009; Wuang et al., 2009) support that children with mild ID show delays in motor development and motor skill-learning, as well as perceptual and sensory-motor deficits. In addition to these deficits, children with ID also display poor performance in sensory integration and manual dexterity tasks (Vuijk et al., 2010). Furthermore, they also exhibit deficits in visual-motor integration skills, which are considered as the coordination of fine motor control and visual perceptual abilities (Memisevic & Sinanovic, 2012). Accordingly, the level of intellectual disability could be indicated as a significant predictor of visual motor integration. All the aforementioned deficits render children apathetic and influence their orientation and mobility as well.

Given the rationale provided in the literature review, it is evident, that controlling fine motor performance and providing early detection of perceptual-motor deficits in children with ID using valid, reliable, and accurate assessment tools is a direct priority (Wuang et al., 2009). The development of an assessment tool will eventually provide valid information for the effectiveness of intervention programs aiming to improve sensory motor functionality. This can potentially be implemented in the school environment to promote academic achievements and enhance children's social life (Wuang et al., 2009; Wuang et al., 2008).

In our knowledge, there are no published studies having developed an assessment tool specifically designed to assess and evaluate fine perceptual-motor skills in children with mild intellectual disabilities so far.

Aiming to this, the present study provides converging evidence for the assessment of the fine perceptuo-motor skills of children with mild ID, aged 7-9 years, using a new effective evaluating tool.

The following research questions were posed to be answered:

(1) Is the construction of a valid and reliable fine perceptuo-motor skills' screening tool for children with mild ID feasible?

(2) Does the performance of children aged 7-9 with mild ID differentiate from that of typically developing children with the same chronological and mental age respectively?

(3) Does the performance of typically developing children aged 7-9 in fine motor skills tasks differentiate from that of typically developing preschoolers?

(4) Does the scoring of children with mild ID differentiate between verbal and performance tasks of intelligence tests, such as Wechsler Intelligence Scale for Children (WISC-III)?

2 Methods

2.1 Participants

A total of 129 subjects (63 boys and 66 girls), 4-9-year-olds participated in the current research. 43 children 6.9-9.1-years-old with mild ID were randomly assigned to the working group. The chronological age ranged from 6.9 to 9.1 years (M = 8 years, SD = 0.71) while the mental age ranged from 4 to 6.3 years (M = 5 years, SD = 0.70). These children were enrolled (attended) in the integration classes of primary schools in the counties of Attiki, Aitoloakarnania, Arta, Ioannina, Preveza, Lefkada, and Achaia, in Greece. They were matched to their chronological and mental age (the cognitive developmental level) and their gender with a group of 43 typically developing first school (7-9-years-old) and 43 typically developing preschoolers (4-6-years-old). The children belonging to the two control groups of our sample were enrolled in regular, public elementary schools and kindergartens in the respective counties. According to their parents and teachers reports, they had not attended supportive speech therapy programs and did not have a diagnosis of Specific Learning Disorder (SLD).

Children with mild ID were partially attending inclusion class. They participated in individualized psychoeducational intervention programs, while the rest of their school day they were back to their classroom. Ending their school courses, they returned to their parents or their caregivers. They were selected according to their medical and family history and all children met the inclusion criteria for non-organic reasoning of intellectual disability. Their native language was Greek. Immigrants' children (people that live and work in our country) were excluded because of their different cultural background.

Prior to their participation, all subjects were screened for any history of previous or current psychiatric or neurological signs and had normal vision. The presence of any of those indications was an exclusion criterion. Children with autism, cerebral palsy, sensory and motor impairments were not included in the sample. Similarly, children with chromosomal abnormalities as well as history of perinatal problems and neurological dysfunctions such as head trauma, muscular dystrophy and epilepsy were also excluded from the study. Based on their parents' and teachers' interviews, none of these children had experienced severe emotional or behavioral disorders and were all able to understand, communicate and follow the experimental directions given by the researcher. Lastly, prior to commencing the study, consent forms were obtained from all parents and teachers. The study was ethically approved by the Greek Ministry of Education and Religious Affairs.

2.2 Procedure and materials

Children with mild ID were assessed in two separate experimental one-hour procedures each, as following: initially, we assessed the general intelligence quotient (*GIQ*) using the Greek edition of Wechsler Intelligence Scale for Children (Georgas et al., 1997), (as this was the only standardized intelligent test in Greek population at the period the research was conducted) while secondly, we evaluated their fine perceptual-motor skills, using a 32-task-battery of fine perceptual-motor skills (F.P.M.S.B), which was constructed in order to test the research inquiries.

2.3 Wechsler school scale of intelligence (WISC III)

The Greek edition of Wechsler Intelligence Scale for Children (Georgas et al., 1997), was administered. WISC III is aimed at children 6.0 to 16.11 years. It refers to the first school age up to puberty and examines a variety of the child's cognitive skills, as follows: (a) the Verbal Scale includes information, similarities, arithmetic, vocabulary, comprehension, digit span (b) the Non-Verbal Scale includes picture completion, coding, picture sequencing, block design, objects assembly, labyrinths and symbols. WISC III includes a variety of modules to measure the various aspects of the child's cognitive functioning. It consists of modules divided into three categories: the main ones that are mandatory for calculating verbal performance and intelligence index (information, similarities, arithmetic, vocabulary, comprehension, picture completion, coding, picture sequencing, block design, objects assembly), the complementary ones that provide information on cognitive abilities (digit span, symbols), and the optional ones that detect cognitive functions (labyrinths). Modules are administered in a specific sequence depending on the age of the child. The test was administered at the initial evaluation stage to children with mild ID 7-9-years-old (*GIQ* = 50-75 [M = 62.42, *SD*= 8.16]; *VIQ* = 54-82 [M = 65.84, *SD* = 8.01]; *PIQ* = 49-87 [M= 68.09, *SD* = 9.69]).

2.4 Battery of fine perceptual-motor skills (F.P.M.S.B.)

Each task of the battery was selected based on its content as well as on other practical factors such as low level of difficulty and accessibility. All the materials used consisted of everyday playful objects for every child. All tasks were designed to be both interesting and familiar to the children in order to increase their motivation to participating in the study and were presented as a role playing. No feedback was given, and the child was not aware of whether he/she completed the task successfully or not.

Thirty two well specified tasks were included, as following: 1) Copy of Shapes, 2) The Maze, 3) Connecting Dots, 4) Coloring Within Contour, 5) Connecting two Parallel Lines With Vertical Ones within 15s, 6) Thread Beads into a String Within 30s, 7) Winding Thread into a Spool Within 15s, 8) Putting Matches in Matchbox With two Hands Simultaneously Within 20s, 9) Paper Folding, 10) Contour Cutting, 11) Throwing Coins in a Slot Within 15s, 12) Putting Pegs in the Pegboard Within 25s, 13) Putting Dots at 30 Circles Within 60s, 14) Put Threader Inside a Needle (Three attempts), 15) Ladder Construction by Imitation Within 15s, 16) Putting Coins Into Drawn Circles Within 20s, 17) Fastening Buttons Within 30s, 18) Unfastening Buttons Within 30s, 19) Putting Paper Clips Into Thick Paper Within 60s, 20) Making a Ball of Rice Paper Within 7s With the Right Hand, 21) Making a Ball of Rice Paper Within 7s With the Left Hand, 22) Sewing Paperboard With String Within 60s, 23) Right Finger Tapping for 10s, 24) Left Finger Tapping for 10s, 25) Touching the Thumb With the Right Index Finger While Stretching the Rest Fingers for 10s, 26) Touching the Thumb With the Left Index Finger While Stretching the Rest Fingers for 10s, 27) Tapping With Right Hand for 10s, 28) Tapping With Left Hand for 10s, 29) Touching the Thumb With the Fingertips of the Right Hand Within 10s for 3 Consecutive Times, 30) Touching the Thumb With the Left Hand Fingertips Within 10s for 3 Consecutive Time, 31) Alternating Flexioning-Stretching Right-Hand Fingers for 10s, and

32) Alternating Flexioning-Stretching Left-Hand Fingers for 10 s (see Table S1 in supplemental material for the fine perceptual-motor skills battery (F.P.M.S.B.).

The execution time of tasks was determined by conducting a pilot-study to our sample.

3 Results

3.1 Reliability and validity test of battery of fine perceptual-motor skills

Aiming to investigate the question of constructing a valid and reliable fine perceptual-motor skills' screening tool for children with mild ID, we tested the validity and reliability of our 32 tasks that assess fine perceptual-motor deficits in children with mild ID.

Therefore, to test for reliability, we estimated the internal consistency using the Cronbach's alpha, whose value was 0.8 ($a = 0.8$) for children with ID, 0.87 ($a = 0.87$) for typically developing children, and 0.86 ($a = 0.86$) for typical pre-school children (see Table S2). The Cronbach's alpha for all subjects (N = 129) was 0.90 ($a = 0.90$), indicating that all 32 tasks were reliable, thus, demonstrating high internal consistency. The value of 0.90 indicates that 90% of the variance is actual scaling and the remaining 10% is error variation. We note that all tasks contribute to the internal consistency and reliability of the test, since if any item is deleted, the coefficient decreases. The average of the battery is 360.10. No average of the scale is greater than the average of the total scale if any question is deleted. The scale variation is 5499.26. No variation of the scale if any question is deleted is smaller than the variation of the total scale.

The results of the reliability analysis show that the battery is highly reliable and all questions contribute to the internal consistency of the test.

The large number of tasks that show statistically significant correlations with the overall performance index as well as the high value of Cronbach's alpha, indicate a remarkable level of internal consistency. The results showed that the scores of all items had statistically significant correlations with the total score.

The structural validity was tested during the test construction process, using the method of factor analysis. In order to test for the structural validity of our evaluation tool, we applied the principal component factor analysis with orthogonal rotation of axes (varimax rotation).

The factor analysis revealed the presence of six factors with eigenvalues greater than 1.0, interpreting 66.88% of the total tasks (hereafter: variances) in our data (see Table S3). The first factor named "Eye-hand Coordination", consists of nine variables (8, 10, 2, 16, 1, 22, 13, 9, 15) and interprets 16.52% of the total variance. The second factor, "Wrist-Fingering Speed", consists of six variables (28, 24, 27, 23, 5, 11) and interprets 15.6% of the total variance. The third factor, "Bilateral Motor Coordination of Two Hands", consists of eight variables (18, 17, 7, 4, 3, 19, 6, 12) and explains 13.37% of the total variance. The fourth factor, "Accuracy in Targeting", consists of five variables (25, 20, 21, 14, 26) and interprets 8.12% of the total variance. The fifth factor, "Thumb-Finger Synchronization", consists of two variables (29, 30) and explains 7% of the total and variance. Finally, the sixth factor, "Finger Dexterity", consists of two variables (32, 31) and interprets 6.18% of the total variance (see Table S4).

3.2 Comparison of fine motor skill performances between children with mild ID and typically developing school aged children and preschoolers

In order to test whether performance of children with mild ID 7-9-year-olds with mild ID differ from that of typically developing children with the same chronological and mental age and from that of typically developing preschoolers, we proceeded to One-way ANOVA (Table 1).

Table 1 Univariate Analysis of Variance (One-Way ANOVA)

Sources of Variance	Sum of Squares	df	Mean Square	F ratio	p
Between Groups Variation	316910.713	2.000	158455.357	51.591	0.000
Within Groups Variation	386996.977	126.000	3071.405		
Total Variation	703907.690	128.000			

The results of the Univariate analysis of variance (One-Way ANOVA) showed statistically significant differences ($F = 51.591$, $p = 0.000 < 0.01$) between the three groups (in their fine perceptual-motor skills performance) with the probability of error 0.01.

However, in order to delineate specific characteristics that could potentially affect the mean motor performance of the three groups, we proceeded to the Tukey HSD multiple comparison criterion (Table 2).

Table 2 Multiple Comparisons Tukey HSD Test Between the Three Groups of Children

(I) Category	(II) Category	Mean Difference (I-II)	SE	p	95% Confidence interval	
					Lower	Upper
Children with mild ID 7-9-years-old	Typically developing children 7-9-year-old	-71.535	0.952	0.000	-99.880	-43.190
	Typically developing preschoolers	49.186	0.952	0.000	20.840	77.530
Typically developing children 7-9-years-old	Children with mild ID 7-9-years-old	71.535	0.952	0.000	43.190	99.880
	Typically developing preschoolers	120.721	0.952	0.000	92.370	149.070
Typically developing preschoolers	Children with mild ID 7-9-years-old	-49.186	0.952	0.000	-77.530	-20.840
	Typically developing children 7-9-years-old	-120.721	0.952	0.000	-1.49E2	-92.370

Notes: The mean difference is significant at the 0.05 level

The Tukey HSD criterion revealed a statistically significant difference between the mean motor performance of the mild ID and the two groups of the typically developing children (p = 0.000, $p < 0.05$).

More specifically, the mean difference in motor performance of children with mild ID and typical developing children of equal chronological (M = -71.535, SE = 11.95) and equal Mental Age (M = 49.186, SE = 11.95) were statistically significant at a level of 0.05.

It was also observed that there is a statistically significant difference between the mean total scores of the typically developing children 7-9-years-old and the typically developing preschoolers (p = 0.000, $p < 0.05$). More specifically, the average difference in motor performance of typically developing children 7-9-years-old and typical developing preschoolers (M = 120.721, SE = 11.52) is statistically significant at a significance level of 0.05.

3.3 Performances of children with mild ID in verbal and non-verbal subscales of WISC III

In order to examine whether there are statistically significant differences between the mean performance of children with mild ID in Verbal and Non-Verbal subscales of WISC III, we performed a t-Test for the Equality of Mean Performances on independent samples (Table 3).

Table 3 Levene's Test in Verbal and Non-Verbal Subscales of WISC III

		Levene's Test for equality of variances					Mean	SE	Levene's Test	
		F	p	t	df	p			Lower	Upper
Mean Performance in WISC III	Equal variances assumed	0.872	0.356	11.330	41.000	0.193	0.480	0.360	-0.253E-1	1.21969
	Equal variances not assumed			11.320	39.590	0.190	0.480	0.370	-0.257E-1	1.223

The initial scoring of the 11 subscales of the WISC III was converted to t-scores expressed in a common metric scale with a mean value of 10 and a standard deviation equal to three. T-scores range from one to 19 and extend by three standard deviations (each one equal to three) around the mean of 10. The subscales where the observed the t-score exceeded 13 (10+3) are indicative of highly developed while subscales with observed scores below seven (10-3) are indicative of less well- developed mental abilities.

The results of the t-test revealed $p = 0.012 < 0.05$ indicating that the mean performance in the Verbal Subscale differs significantly from the corresponding performance in the Non-verbal. Children with mild intellectual disability of 7-9-year-olds performed better in the WISC III Non-verbal subscale than in the Verbal one, a statistically significant difference at the level of 0.05.

Specifically, children with mild ID score lower in Verbal Subscales specifically in Arithmetic (M = 3.04, SD = 2.94) and Similarities (M = 4.23, SD = 2.31). Their best performance was recorded in the Non-Verbal Subscales such as Coding (M = 6.48, SD = 2.85) and Objects Assembly (M = 6.09, SD = 2.23) (Table 4).

4 Discussion

4.1 Implications of the study

In the present study we tried to shed light on previously unexplored interrelations and therefore, provide an assessment tool for identifying potential deficits in the development

Table 4 Mean Scores of Children with Mild ID, 7-9-YearS-Old in Verbal and Non-Verbal Subscales of WISC III

	Mean scores of Verbal subscales of WISC III					Mean scores of non-Verbal subscales of WISC III				
	Verbal subscales	M	Range		SD	Non-verbal subscales	M	Range		SD
Children with mild ID 7-9-years-old	Information	5.16	2.00	8.00	1.62	Picture completion	4.35	1.00	9.00	2.30
	Similarities	4.23	1.00	9.00	2.32	Coding	6.49	2.00	12.00	2.86
	Arithmetic	3.05	1.00	12.00	2.94	Picture sequencing	5.05	3.00	10.00	1.46
	Vocabulary	5.95	2.00	9.00	1.45	Block design	5.51	3.00	8.00	1.16
	Comprehension	5.51	2.00	10.00	1.97	Objects Assembly	6.09	3.00	12.00	2.23
	Digit span	4.37	1.00	9.00	2.27					

of fine perceptual-motor skills in children with mild ID compared to age-matched typically developing children. Thus, focusing on gaps in the existing research studies we sought to examine whether: a) it is feasible the construction of a valid and reliable fine perceptual-motor skills' screening tool for children with mild ID b) children 7-9-years-old with mild ID differentiate their performance from that of typically developing children with the same chronological and mental age respectively c) the performance of typically developing children 7-9-years-old in fine motor skills tasks differentiate from that of typically developing preschoolers and children with mild ID differentiate their performances at verbal and non-verbal subscales of the intelligence test WISC III.

4.2 Reliability and Validity Test of Battery of Fine Perceptual-Motor Skills

The results of the reliability and validity testing have shown that the battery of fine perceptual-motor skills we designed is a reliable and valid tool. It is a unique, easy-to-use, objective, valid, reliable and comprehensive tool for assessing fine perceptual and motor skills. By covering a variety of skills, it enables us to assess thoroughly the level of perceptual-motor development of the child, to detect for potential deficits, and to design and implement individualized psycho-educational intervention programs. The grouping of six areas gives the teacher the opportunity to use it partially, as it reduces the burden of responses and facilitates its effective implementation, which is particularly useful for intellectually disabled children who facing difficulties focusing their attention.

4.3 Performances of Children with Mild ID and Typically Developing Children in Fine Perceptual-Motor Skills Tasks

According to the statistically significant differences in fine motor skill performances between the three groups ($p = 0.000 < 0.01$), we can observe that children with mild ID, 7-9-years-old show significantly lower performance in fine perceptual-motor tasks compared to typical developing children of equal age, but significantly higher performance than the group of typically developing children of the same mental age (preschoolers). These results showed that the chronological age and intelligence quotient influence fine motor performance considerably. It reveals that these factors contribute to fine motor development and refinement.

4.4 Performances of Children with Mild ID in Verbal and Non-Verbal Scales of WISC III

The statistically significant differences ($p = 0.012 < 0.05$) between Verbal and Non-Verbal subscales of WISC III, indicate that the children with mild ID scored higher at Non-Verbal scale of WISC III (that scale assesses intelligence via visuo-motor way).

These findings agree with previous research studies supporting that Non-verbal IQ score is higher than Verbal and General IQ in intellectually disabled children (Tylenda et al., 2007) especially in children with familial/environmental retardation (Maris et al., 2013), as children who participated in our study. The aforementioned results are predictable as: a) Verbal IQ is interrelated with knowledge provided by school and children's socio-cultural environment, and b) low socioeconomic status of intellectually disabled impede the provision of appropriate educational stimulants and high motivation of achievement. Parents are not demanding for school studying and learning issues.

The results presented in this study are consistent with previous studies using standardized psychomotor tests, according to which, children with mild mental retardation manifest weak fine perceptual-motor performance compared to age-matched children (Sherill, 1999; Su et al., 2008).

As previously discussed, it has been well established that perceptual-motor and cognitive development in children proceed to the same level. Intellectual Disability is often accompanied with deficits in perceptual-motor skill at approximately the same extend as cognitive dysfunctions (Di Blasi et al., 2007).

Specifically, school-aged children with moderate ID score significantly lower on almost all items regarding motor skill on the Bruininks-Oseretsky Test of Motor Proficiency, compared to students with borderline and mild intellectual disabilities (Jeoung, 2018). The degree and extent of perceptuo-motor deficits of intellectually disabled is directly depended on the level of intellectual disability and environmental experiences (De Giorgio, 2017; Goutziamani-Sotiriadi, 1993). Individuals with mild ID exhibit a delay in the acquisition of motor milestones (Aharoni, 2005; Elliott & Bunn, 2004), as well as a dysfunction in sensory-motor behaviour, which influences their sensory, neuromuscular and motor systems (Hogan et al., 2000). On one hand, children with ID indicate quantitative differences when are compared to their typically developing peers as a result of the delay they present in the rate of neuromuscular maturation (Liu & Chakkalakal, 2018). On the other hand, they display qualitative differences as a result of difficulties in appropriate task execution due to limited motor experiences, restricted motor interaction and practice. It is commonly known that the limited learning experiences and repetition impede the development and refinement of perceptual-motor skills of children with ID (Polychronopoulou, 2004).

Specifically, lack of proper and sufficient training lead to a delay in muscle tone development, improvement and enrichment of these skills, in terms of speed, intensity, duration, pace, and automation, as well as in the acquisition of new motor patterns and skills (Goutziamani-Sotiriadi, 1993). It seems that their perceptual-motor deficits are associated with developmental factors (Raz et al., 2000). Therefore, defining the perceptual motor development of mild ID individuals as "delayed" makes a necessity the implementation of intervention programs aiming at providing stimulation (Vermeer & Davis, 1995). According to Aharoni (1996), the motor behaviour of the children with ID varies and is dependent on the level of intellectual functioning (mental age), chronological age, and experience. As biological age progresses so does the level of maturation of specific neural mechanisms, as well as the quantity of multiple learning experiences through the process of practice and training. An enriched environment can stimulate the acquisition of motor skills and could partially repair neuronal impairment due to exploration and motor activity (De Giorgio, 2017).

The practice of motor skills enhances the development of myelination, the maturation of motor and interstitial nerve fibers (connective areas), contributes to increased intersection of the nerve cells of the cerebral cortex and the creation of new blood vessels, which are elements that define at a great extent motor development and execution of tasks (Kambas et al., 2002; De Barros et al.,, 2003). Therefore, the higher fine motor performance of children with mild ID in comparison to that of typically developing pre-schoolers, was expected. The increase in time difference between the two groups is accompanied by changes at the level of neuromuscular maturation and perfection of motor patterns with the contribution of factors, such as learning history and background, academic experience, and individual performance training (Bürki et al., 2014).

In conclusion, we support that the development of emerging fine motor skills, as well as their potentiality of refinement, depends on the extent of guidance and training provided. More specifically, the performance related to the speed and dexterity of the hands increases with the progression of age as they are used more extensively in daily life and academic activities (Duger et al., 1999). Visual motor integration skills are very important for a child's overall level of functioning. Individualized programs for the remediation of visual-motor integration skills should be a part of the curriculum for children with mild ID (Memisevic & Sinanovic, 2012).

5 Conclusions

In accordance with the results of our study, we conclude that children with mild ID, 7-9 years old show significantly lower performance in fine perceptual-motor tasks compared to typical developing children of equal age. They also displayed significantly higher performance in fine perceptual-motor tasks than the group of typically developing children of the same mental age (preschoolers). Moreover, they scored higher at Non-Verbal than Verbal Scale of the WISC III.

Typically developing children 7-9-years-old showed higher performance in fine perceptual-motor tasks than typically developing preschoolers.

Finally, the battery of tasks consists a unique, usable, valid, reliable, fine, comprehensive, perceptual-motor skills assessment tool. Incorporating a wide range of skills, it enables us to examine thoroughly the child's perceptual-motor developmental level. It constitutes a screening tool for possible deficits in the area of fine motor mobility and providing us the opportunity to design and implement better individualized psycho educational intervention programs. The validity and clinical relevance of the present tool should be elucidated further in future larger studies.

Compliance with ethical standards

The study was performed in accordance with the ethical standards of the Research Committee of University of Ioannina and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all individual adult participants included in the study, and assent was obtained from children.

Conflicts of interest

The authors declare they have no conflicts of interest.

References

Aggelopoulou-Sakadami, N. (1999). Special education. Basic principles and methods. Christodoulidis.

Aharoni, H. (2005). Adapted physical activities for the intellectually challenged adolescent: Psychomotor characteristics and implications for programming and motor intervention. International Journal of Adolescent Medicine and Health, 17(1), 33-47. https://doi.org/10.1515/IJAMH.2005.17.1.33

Beirne-Smith, M., Patton. J., & Kim, S. (2006). Mental retardation. An introduction to intellectual dis-abilities. Pearson Prentice Hall.

Bürki, C., Ludwig, C., Chicherio, C., & Ribaupierre, A. (2014). Individual differences in cognitive plasticity: an investigation of training curves in younger and older adults. Psychological Re-search, 78(6), 821-835. https://doi.org/10.1007/s00426-014-0559-3

De Barros, K.M., Fragoso, A.G., De Oliveira, A.L., Cabral-Filho, J.E., & De Castro, R.M. (2003). Do environmental influences alter motor abilities acquisition? Arquivos de Neuropsiquiatria, 61(2-A), 170-175. https://doi.org/10.1590/S0004-282X2003000200002

De Giorgio, A. (2017). The roles of motor activity and environmental enrichment in intellectual disability. Somatosensory and Motor Research, 34(1), 34-43. https://doi.org/10.1080/08990220.2016.1278204

Di Blasi, F., Elia, F., & Buono, S. (2007). Relationships between visual-motor and cognitive abilities in intellectual disabilities. Perceptual and Motor Skills, 104, 763-772. https://doi.org/10.2466/pms.104.3.763-772

Duger, T., Bumin, G., Uyanik, M., Aki, E., & Kayihan, H. (1999). The assessment of Bruininks-Oseretsky test of motor proficiency in children. Pediatric Rehabilitation, 3(3), 125-131. https://doi.org/10.1080/136384999289531

Elliott, D., & Bunn, L. (2004). Motor disorders in children with intellectual disabilities. In D. Dewey, & D. E. Tupper (Eds.), Developmental Motor Disorders: A Neuropsychological perspective. (pp. 137-151). Guilford Press.

Farrell, M. (2003). The Special Education Handbook. 3rd Ed., David Fulton Publishers.

Garcia-Nonell, C., Rigau-Ratera, E., & Artigas-Pallares, J. (2006). The Neurocognitive Profile of Non-Verbal Learning Disorder, Revista de Neurologia, 43(5), 268-274. https://doi.org/10.33588/rn.4305.2005574

Georgas, D., Paraskevopoulos, I.N., Bezevegis, H., & Giannitsas, N.D. (1997). Wechsler intelligence scale for children (WISC-III GR). Ellinika Grammata.

Giagazoglou, P., Katsimani, G., Sidiropoulou, M., & Materi, D. (2009). Assessment of motor development and sex differences in teenagers with moderate intellectual disabilities. Themes of Spe-cial Education, 43, 3-17.

Goutziamani-Sotiriadi, K. (1993). Children with special educational needs. Goutziamani-Sotiriadi.

Hogan, D.P., Rogers, M.L., & Msall, M.E. (2000). Functional limitations and key indicators of well-being in children with disabilities. Archives of Pediatrics and Adolescent Medicine, 154, 1042-1048. https://doi.org/10.1001/archpedi.154.10.1042

Houwen, S., Visser, L., Van der Putten, A., & Vlaskamp, C. (2016). The interrelationships between motor, cognitive, and language development in children with and without intellectual and de-velopmental disabilities. Research in Developmental Disabilities, 53-54, 19-31. https://doi.org/10.1016/j.ridd.2016.01.012

Jenni, O.G., Chaouch, A., Caflisch, J., & Rousson, V. (2013). Correlations between motor and intellec-tual functions in normally developing children between 7 and 18 years. Developmental Neuro-psychology, 38(2), 98-113. https://doi.org/10.1080/87565641.2012.733785

Jeoung, B. (2018). Motor proficiency differences among students with intellectual disabilities, autism, and developmental disability. Journal of Exercise Rehabilitation, 14(2), 275-281. https://doi.org/10.12965/jer.1836046.023

Kambas, A., Aggelousis, N., Proviadaki, E., Taxildaris, K., & Mavromatis, G. (2002). Pilot standardization of assessment battery of motor development MOT 4-6 in Greek preschoolers. Sport and Society, 30, 28-37.

Kartasidou, L. (2004). Learning via motor. Theoretical approaches & educa-tional applications of psychomotricity in special education. University of Macedonia.

Kennedy, J., Brown, T., & Chien, C.W. (2012). Motor skill assessment of children: is there an association between performance-based, child report, and parent-report measures of children's motor skills? Physical and Occupational Therapy in Pediatrics, 32(2), 196-209. https://doi.org/10.3109/01942638.2011.631101

Liu, W, & Chakkalakal, J.V. (2018). The Composition, Development, and Regeneration of Neuromuscular Junctions. Current Topics of Developmental Biology, 126, 99-124. https:/doi.org/10.1016/bs.ctdb.2017.08.005 https://doi.org/10.1016/bs.ctdb.2017.08.005

Maris, A.F., Barbato, I.T., Trott, A., & Montano MA. (2013). Familial mental retardation: a review and practical classification. Ciencia and Saude Coletiva, 18(6), 717-729. https://doi.org/10.1590/S1413-81232013000600023

Memisevic, H., & Djordjevic, M. (2018). Visual-motor integration in children with mild intellectual disability: A meta-analysis. Perceptual and Motor Skills, 125(4), 696-717. https://doi.org/10.1177/0031512518774137

Memisevic, H., & Sinanovic, O. (2012). Predictors of visual-motor integration in children with intellectual disability. International Journal of Rehabilitation Research, 35(4), 372-374. https://doi.org/10.1097/MRR.0b013e32835a23d0

Polychronopoulou, S. (2004). Children and teenagers with special needs and abilities. Mental retardation. Psychological, sociological and educational approach (Vol. 2). Atrapos.

Raz, N., Williamson, A., Gunning-Dixon, F., Head, D., & Acker, J.D. (2000). Neuroanatomical and cognitive correlates of adult age differences in acquisition of a perceptual-motor skill. Micro-scopic Research Techniques, 51, 85-93. https://doi.org/10.1002/1097-0029(20001001)51:1⟨85::AID-JEMT9⟩3.0.CO;2-0

Rintala, P., & Loovis, E.M. (2013). Measuring motor skills in Finnish children with intellectual disabilities. Perceptual and Motor Skills, 116(1), 294-303. https://doi.org/10.2466/25.10.PMS.116.1.294-303

Sherill, C. (1999). Adapted Physical Activity Recreation and Sport. WCB/ Mc Graw-Hill.

Smits-Engelsman, B., & Hill, E.L. (2012). The relationship between motor coordination and intelligence across the IQ range. Pediatrics, 130(4), 950-956. https://doi.org/10.1542/peds.2011-3712

Su Chwen-Yng et al. (2008). Profiles and cognitive predictors of motor functions among early school-age children with mild intellectual disabilities. Journal of Intellectual Disability Research, 1-13.

Tylenda, B., Beckett, J., Barrett, R. (2007). Assessing mental retardation using standardized intelli-gence tests. International Review of Research in Mental Retardation, 34, 27-97. https://doi.org/10.1016/S0074-7750(07)34002-0

Vermeer, A., & Davis, W.E. (1995). Physical and Motor Development in Mental Retardation:[based on presentations made at the Ninth World Congress of the IASSMD held on the Gold Coast, Australia, in 1992]. S. Karger Pub.

Vuijk, P.J., Hartman, E., Scherder, E., & Visscher, C. (2010). Motor performance of children with mild intellectual disability and borderline intellectual functioning. Journal of Intellectual Disability Research, 54(11), 955-965. https://doi.org/10.1111/j.1365-2788.2010.01318.x

Wuang, Y.P., Su, C.Y., & Huang, M.H. (2012). Psychometric comparisons of three measures for assessing motor functions in pre-schoolers with intellectual disabilities. Journal of Intellectual Disability Research, 56(6), 567-578. https://doi.org/10.1111/j.1365-2788.2011.01491.x

Wuang, Y.P., Wang, C.C., Huang, M.H., & Su, C.Y. (2009). Prospective study of the effect of sensory integration, neurodevelopmental treatment, and perceptual-motor therapy on the sensorimotor performance in children with mild mental retardation. American Journal of Occupational Ther-apy, 63, 441-452. https://doi.org/10.5014/ajot.63.4.441

Wuang, Y.P., Wang, C.C., Huang, M.H., & Su, C.Y. (2008). Profiles and cognitive predictors of mo-tor functions among early school-age children with mild intellectual disabilities. Journal of In-tellectual Disability Research, 52(12), 1048-1060. https://doi.org/10.1111/j.1365-2788.2008.01096.x

Supplement

Table S1 Fine perceptual-motor skills battery (F.P.M.S.B.)

N	Tasks	Instructions	Tools required
1	Copy the shapes	Copy the shapes into the opposite boxes	Pen and paper
2	The Maze	From the starting point and using a pen, follow the path to exit the maze	Pen and paper
3	Connecting dots	Connect each dot to create an object	Pen and paper
4	Color inside the contour	Add color to the printed objects while staying inside the contour	Coloring pens and paper
5	Connecting parallel lines with vertical ones	Connect two parallel lines with a vertical one	Pen and paper
6	Stringing beads	Place as many beads as possible on a string	Beads and string
7	Winding thread into a spool	Wind the thread into the spool	Spool, thread
8	Putting matches in matchbox with two hands simultaneously within 20s	Place all matches inside the match box using both hands	Match box, matches
9	Paper folding	Fold a paper in half	Paper
10	Contour cutting	Using scissors, cut the contour of the printed object	Scissors and a paper
11	Throwing coins in a slot within 15s	Throw the coins inside the piggy bank	Coins and a piggy bank
12	Putting pegs in the pegboard within 25s	Place each peg in the pegboard within 25s	Pegboard, pegs
13	Putting dots at 30 circles within 60s	Place 1 dot in every circle separately	Pen and paper
14	Place threader inside a needle	Hold the threader between your thumb and index fingers and place it inside the needle	Needle and threader
15	Ladder construction by imitation within 15s	Construct a ladder with these cubes	Wooden cubes
16	Putting coins into drawn circles within 20s	Place all the coins into the circles	Coins and a paper
17	Fastening buttons within 30s	Fasten the buttons of your jacket	Jacket with buttons
18	Unfastening buttons within 30s	Unfasten the buttons of your jacket	Jacket with buttons
19	Putting paper clips into thick paper within 60s	Put these paperclips into the paper	Paperclips, thick paper
20	Making a ball of rice paper within 7s with the right hand	Make a ball with the rice paper using your right hand	Rice paper
21	Making a ball of rice paper within 7s with the left hand	Make a ball with the rice paper using your left hand	Rice paper
22	Sewing paperboard with string within 60s	Sew that paperboard with this string	Paperboard, string
23	Finger tapping for 10s	Tap your right finger on the desk	
24	Finger tapping for 10s	Tap your left finger on the desk	
25	Touching thumb and right index finger while stretching the rest fingers for 10s	Touch your right thumb with your right index for 10s	
26	Touching thumb and left index finger while stretching the rest fingers for 10s	Touch your left thumb with your left index for 10s	
27	Tapping with right hand for 10s	Tap your right hand on the desk for 10s	
28	Tapping with left hand in two places for 10s	Tap your left hand on the desk for 10s	
29	Touching the thumb with the fingertips of the right hand within 10s for 3 consecutive times	Touch your right thumb with your fingertips for 3 consecutive times within 10s	
30	Touching the thumb with the left hand fingertips within 10s for 3 consecutive times	Touch your left thumb with your fingertips for 3 consecutive times within 10s	
31	Alternating flexioning-stretching right-hand fingers for 10s	Alternate flexioning-stretching your right-hand fingers for 10s	
32	Alternating flexioning-stretching left-hand fingers for 10s	Alternate flexioning-stretching your left-hand fingers for 10s	

Table S2 Reliability analysis Cronbach's Alpha of the battery

Variables	Scale mean if item deleted	Scale variance if item deleted	Corrected item-total correlation	Squared multiple correlation	Cronbach's Alpha if item deleted
1	346.023	4610.070	0.830	0.850	0.890
2	357.496	5336.846	0.560	0.551	0.899
3	358.783	5390.703	0.671	0.696	0.900
4	358.620	5381.019	0.742	0.712	0.900
5	356.806	5331.845	0.521	0.508	0.899
6	353.434	5229.435	0.804	0.815	0.897
7	267.915	3953.875	0.533	0.509	0.938
8	355.884	5245.885	0.602	0.560	0.898
9	359.543	5456.719	0.574	0.561	0.902
10	358.845	5378.398	0.719	0.724	0.900
11	351.380	5309.394	0.736	0.683	0.898
12	350.822	5297.523	0.735	0.776	0.898
13	336.496	4967.814	0.594	0.588	0.896
14	357.868	5447.240	0.391	0.305	0.901
15	356.729	5374.949	0.626	0.557	0.900
16	357.101	5350.669	0.542	0.535	0.900
17	356.651	5335.510	0.683	0.689	0.899
18	356.233	5364.570	0.596	0.608	0.900
19	352.992	5024.336	0.694	0.706	0.895
20	359.543	5464.969	0.462	0.527	0.902
21	359.512	5466.330	0.448	0.504	0.902
22	352.845	5156.866	0.657	0.604	0.896
23	334.581	4767.277	0.812	0.830	0.891
24	337.248	4846.469	0.803	0.847	0.892
25	344.752	5175.844	0.547	0.575	0.897
26	345.783	5140.593	0.571	0.596	0.897
27	331.930	4713.878	0.845	0.900	0.890
28	334.442	4818.624	0.815	0.903	0.891
29	358.186	5418.949	0.407	0.526	0.901
30	357.938	5423.152	0.431	0.542	0.901
31	348.395	5221.100	0.571	0.639	0.898
32	348.349	5273.588	0.456	0.593	0.899

Table S3 Total variance explained

Components	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	14.594	45.605	45.605	14.594	45.605	45.605	5.289	16.528	16.528
2	1.598	4.995	50.600	1.598	4.995	50.600	4.994	15.606	32.134
3	1.445	4.517	55.117	1.445	4.517	55.117	4.281	13.378	45.512
4	1.352	4.224	59.341	1.352	4.224	59.341	2.599	8.121	53.633
5	1.275	3.985	63.327	1.275	3.985	63.327	2.263	7.071	60.704
6	1.138	3.557	66.884	1.138	3.557	66.884	1.978	6.180	66.884
7	0.963	3.010	69.894						
8	0.923	2.884	72.778						
9	0.835	2.609	75.387						
10	0.819	2.560	77.947						
11	0.726	2.268	80.215						
12	0.645	2.016	82.231						
13	0.588	1.838	84.069						
14	0.527	1.647	85.716						
15	0.462	1.445	87.162						
16	0.440	1.375	88.537						
17	0.434	1.356	89.893						
18	0.358	1.120	91.013						
19	0.351	1.096	92.109						
20	0.343	1.071	93.180						
21	0.296	0.925	94.105						
22	0.265	0.827	94.931						
23	0.242	0.757	95.688						
24	0.224	0.699	96.387						
25	0.222	0.694	97.082						
26	0.209	0.653	97.735						
27	0.182	0.570	98.305						
28	0.142	0.444	98.749						
29	0.127	0.396	99.145						
30	0.123	0.384	99.528						
31	0.095	0.296	99.824						
32	0.056	0.176	100.000						

Notes: Extraction method: Principal component analysis

Table S4 Rotated component matrix

Components	Factors					
	1	2	3	4	5	6
N. 8	0.733					
N. 10	0.700	0.328	0.355			
N. 2	0.685					
N.16	0.650		0.309			
N. 1	0.641	0.460	0.354			
N. 22	0.547	0.314		0.341		
N. 13	0.484				0.415	
N. 9	0.429		0.352			
N. 15	0.404	0.331		0.345		
N. 28	0.323	0.805				
N. 24		0.781				
N. 27	0.408	0.731				
N. 23	0.383	0.710				
N. 11	0.351	0.532	0.390			
N. 5		0.502	0.395			
N. 18			0.728			
N. 17			0.707			
N. 7			0.589			0.304
N. 4	0.411	0.356	0.538			
N. 3	0.384	0.432	0.527			
N. 19	0.487	0.367	0.503			
N. 6	0.470	0.440	0.490			
N. 12	0.480	0.342	0.481	0.399		
N. 25		0.329		0.662		
N. 20	0.414			0.567		
N. 14			0.466	0.561		
N. 26		0.436		0.535		0.330
N. 21			0.374	0.483		
N. 29					0.838	
N. 30					0.796	
N. 32						0.771
N. 31						0.738

Notes: Rotation converged in 9 iterations. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser normalization.

