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The relationship between motor function and visual perception in school-aged children with neurodevelopmental disorders

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Abstract

Motor function and visual perception are key areas of occupational performance skills in which children with neurodevelopmental disorders have deficits that affect their daily activities and tasks, such as writing.

Aim: The aim of this study was to investigate the relationship between motor function and visual perception in children with Autism Spectrum Disorder (ASD) and Attention Deficit Hyperactivity Disorder (ADHD) and explore differences in performance between the groups.

Methodology: We reviewed the file records of 60 school-aged children (51 boys/9 girls), 30 with ASD (M = 8.53 years) and 30 with ADHD (M = 8.42 years), derived from a university Child Psychiatry Department and including assessments in visual perception (Developmental test of Visual Perception- DTVP-2) and motor function (Movement ABC2- M-ABC2).

Results: Results indicated a significant correlation between total motor function performance scores and visual-motor integration categories in children with ASD (r(28)=.70, p<.001) and ADHD (r(28)=.40, p=.03). Manual dexterity and balance were found to predict performance on visual-motor integration in both ASD (F (2,27)=10.94, p<.001) and ADHD (F(1,28)=8.45, p=.007). Children with ASD performed lower than ADHD children in the categories of Aiming and Catching (p=.032) and Balance (p<.001).

Conclusions: The findings of the present study highlight the interrelationships between motor function and visual perception as it is manifested in children with ASD and ADHD at school age. In-depth knowledge of how motor function relates to visual perception offers valuable insights, therapeutically and research-wise, to enhance participation in daily activities of children with neurodevelopmental disorders.

Keywords: Visual perception; Motor function; Neurodevelopmental disorders; Autism Spectrum Disorder; Attention Deficit Hyperactivity Disorder

1. Introduction

Visual perception and motor function skills enable the child to interact with the environment and seek new sensory-motor experiences (Bakke et al., 2019) [1]. Since body movements and visual perception are important factors in the learning process during childhood, a plethora of studies have focused on studying the connection between motor function and visual perception, highlighting the importance of their relationship during childhood and school age (Kurtz, 2006; Tepeli, 2014) [2][3]. The research activity on this topic in relation to neurodevelopmental disorders is limited, though (Tsai, Wilson & Wu, 2008) [4].

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The prevailing research gap in the clinical population is reflected in the therapeutic interventions. Specifically, the assessment process and therapeutic intervention often focus on highlighting and addressing the core symptoms of the disorder in question, as opposed to identifying deficits in movement and perception, which are equally associated with impairing the child's functioning (Kurtz, 2006) [2]. The reported impairment in functioning of children with neurodevelopmental disorders with co-occurring deficits in movement and visual perception is associated with limited participation in developmentally appropriate occupations (school, self-care, peer group), negatively affecting self-image and feelings of occupation satisfaction (O'Brien & Kuhaneck, 2019) [5].

In addition, an avoidant behavior is adopted when participating in activities and contacting peers, gradually leading to isolation (AOTA,2017) [6]. The perception of visual stimulus directly influences the organization of human motor actions, while its absence limits effective use of the body in the environment and the search for new sensorimotor experiences (Bakke et al., 2019) [1].

Considering the hypothesis of a link between skills (Bakke et al., 2019) [1], we expected to find a significant positive correlation between performance on the motor function assessment tool and visual perception assessment tool in two groups of neurodevelopmental disorders, namely ASD and ADHD. Given the use of the aforementioned visual perception tool to test children's writing-motor performance, the present study attempts to investigate the relationship between motor function and visual perception skills that are mainly used during important tasks in children's daily productivity, such as writing (Hammil, Pearson & Voress, 1993) [7]. Although a plethora of studies in the current literature have focused their research interest on the movement-visual perception relationship in children with motor function difficulties (Bonifacci, 2004; Parush, 1998; Tsai, Wilson & Wu, 2008) [8][9][4], limited studies have included children carrying the diagnoses of ASD and ADHD in their sample. No studies, however, have gone on to look for possible differences in performance between the two diagnoses. Moreover, to our knowledge, only one study has attempted to correlate the performance of the two specific tools for assessing the two functions. However, in order to investigate the contribution of the movement-visual perception relationship to their handwriting performance it included only typically developing children without a specific disorder (Kaiser, Albaret & Doudin, 2009) [10]. Therefore, the focus of the present study is, on the one hand, to look for differences in motor function and visual perception performance of between ASD and ADHD and on the other hand, to investigate the relationship between visual perception and motor function skills in the two groups.

2. Material and methods

2.1. Participants

Data from the files of 60 children, aged 7-10 years, derived from the records of the Autism Clinic and the Outpatient Clinic of a University Child Psychiatry Department were used in the study. The sample consisted of two groups of patients, one with an ASD diagnosis (n=30) and one with an ADHD diagnosis (n=30).

2.2. Inclusion Criteria

In order to be included in the study the files should include patients with: i) a diagnosis of ASD or ADHD received at the Autism Spectrum Disorder Clinic and the Outpatient Clinic of the University Child Psychiatric Department; ii) an age range of 7-10 years; iii) general Intelligence Quotient> 70 according to the Wechsler Intelligence Scale for Children-Third Edition (WISC-III) (Kaufman& Lichtenberger, 2000) [11] iv) available data from the administration of the Movement Assessment Battery for Children- 2 (Movement ABC-2)(Henderson, Sugden & Barnett, 2007) [12] and the Developmental Test of Visual Perception- 2 (DTVP-2)(Hammil, Pearson & Voress, 1993) [7]. The existing data from the reported assessments should have been collected synchronously, with a maximum 3-month difference.

2.3. Exclusion criteria

Data of children who ended up not being included in the survey sample included asynchronous data between occupational therapy assessments and cognitive assessment, data of children with comorbid ASD and ADHD or comorbid with another psychiatric disorder and data of children with concomitant neural, metabolic or genetic syndromes. Furthermore, we excluded data from children who had already received occupational therapy intervention to address deficits in movement and perception.

2.4. Assessment tools

The Developmental Test of Visual Perception- 2 (DTVP-2) was used to detect data in visual perception. It contains 8 major subcategories, which measure different but significantly interdependent functions subject to either the Visual

Motor Integration-VMI domain or the Motor Reduced Perception-Motion Reduced Perception-MRP domain. The sum of the VMI and MRP is defined as the General Visual Perception (GVP) test score. The tests of the reported assessment test fall into the following subcategories:

- *Subcategory 1. Eye- hand Coordination (VMI).*
- *Subcategory 2. Position in Space (Position in Space-MRP)*
- *Subcategory 3. Copying (Copying-VMI)*
- *Subcategory 4. Figure-ground discrimination (Figure- Ground-MRP)*
- *Subcategory 5. Spatial Relations (Spatial Relations-VMI).*
- *Subcategory 6. Visual Closure (Visual Closure-MRP)*
- *Subcategory 7. Visual-Motor Speed (Visual-Motor Speed-VMI)*
- *Subcategory 8. Form Constancy (Form Constancy-MRP)*

The Movement Assessment Battery for Children-2 (Movement ABC-2) is administered to describe the level of motor function and detect possible motor deficits through the child's participation in structured motor tests. It includes three basic categories of motor skills and corresponding tests related to manual dexterity, planning movement through aiming and catching and balance. (Henderson, Sugden & Barnett, 2009) [12].

The Wechsler Intelligence Scale for Children- Third Edition (1991) for the assessment of children's cognitive development, cognition and intelligence, the Autism Diagnostic Observation Schedule (ADOS) Second Edition (2012) for the diagnostic assessment and evaluation of the symptoms associated with ADHD (Western Psychological Services, 2010) [13], as well as the Greek ADHD Assessment Scale V (Kalantzi-Azizi, Angeli & Efstathiou, 2012) [14], as an early detection scale for symptoms suggestive of ADHD (Dupaul, et al., 1998) [15].

2.5. Statistical Analysis

IBM SPSS Statistics was used for data entry, processing and analysis. Mean and standard deviations, as well as minimum and maximum values were used to describe the quantitative variables. Absolute values (N) express the number of the sample in each group. Cognitive potential and age were tested by Student's t-test for possible differences between the two groups of ASD and ADHD. Pearson's (r) and Spearman's (rho) correlation coefficient for non-normal distribution was used to test for possible relationships between the scores of the two assessments. Then, from the statistically significant correlations presented, the variables that showed moderate and high degree of correlation were further studied by multiple linear regression method through backward elimination with a significance level of P_r =0.20 (P_r > P_e). Independent samples t-tests (or the equivalent nonparametric Mann-Whitney test) were performed to compare performance between the two diagnostic groups. Variables that had a normal distribution were subjected to independent samples t-tests, while the remaining variables that did not meet the criterion of normal distribution were subjected to the Mann-Whitney test for non-parametric samples. Statistical significance levels were set at 0.05.

3. Results

The sample consisted of 60 children, equally divided by diagnosis into two groups. From the Student's t-test analysis, no differences in age (t(58)=.41, p=.68) and general intelligence (t(58)=-.60, p=.55) were observed between the two groups (see Table 1).

Table 1 Descriptive Characteristics of the Sample

N=60	**Diagnosis**	
Age	**ASD (N=30)**	**ADHD (N=30)**
Mean	8.537	8.427
SD	1.410	1.215
Min	7.000	7.000
Max	10.800	10.800
WISC		
Mean	103.667	106.267

SD	19.032			14.520		
Min	70.000			75.000		
Max	135.000			138.000		
Sex						
Boys	25 (83%)			26 (87%)		
Girls	5 (17%)			4 (13%)		
M-ABC2 Total Score						
Mean	50.433			65.933		
SD	17.270			16.708		
Min	21.000			27.000		
Max	87.000			113.000		
M-ABC2 Subtests	**MD**	**A&C**	**B**	**MD**	**A&C**	**B**
Mean	19.733	13.700	17.333	24.633	16.300	25.200
SD	8.379	4.786	8.770	8.724	4.388	7.972
Min	6.000	3.000	5.000	9.000	6.000	8.000
Max	33.000	25.000	36.000	55.000	26.000	37.000
DTVP2 Main Subtests	**MRP**	**VMI**	**GVP**	**MRP**	**VMI**	**GVP**
Mean	92.267	92.400	92.233	96.833	97.833	97.467
SD	16.688	18.700	15.321	14.723	12.149	11.389
Min	63.000	52.000	64.000	73.000	72.000	78.000
Max	132.000	128.000	126.000	125.000	123.000	118.000

Note. SD=Standard Deviation, Min=Minimum Value, Max=Maximum Value, MD =Manual Dexterity, A& C= Aiming and Catching, B = Balance, MRP= Motor Reduced Perception, VMI =Visual-Motor Integration, GVP) = General Visual Perception

Regarding the investigation of the correlation between the Movement ABC-2 total motor function scores (see Table 1) and the standardized scores of the DTVP-2 visual perception domains (GVP, MRP, VMI) (see Table 1), a significant correlation was found between Movement ABC2 and the three visual perception domains of children with ASD. However, in children with ADHD, a statistically significant correlation was found only between M ABC-2 performance and the visual-motor integration domain ($r(28)=.40$, $p=.03$). Also, when further investigating the main categories of movement ABC2 and the domains of visual perception, it was found that

manual dexterity was significantly associated mainly with visual-motor integration in both children with ASD ($r(28)=.58$, $p=.02$) and children with ADHD (r_s $(28)=.54$, $p=.002$), while in children with ASD balance was also significantly correlated with visual-motor integration ($r(28)=.63$, $p<.001$) .

Between the three Movement ABC dimensions and the 8 subcategories of the DTVP-2, the 4 subcategories of visual-motor integration were found to be correlated with Manual dexterity and Balance in children with ASD, whereas in children with ADHD only Copying was correlated with Manual dexterity and Balance, and Visuomotor Speed was correlated with Balance only (see Tables 2 and 3).

Table 2 Correlation between the three M-ABC dimensions and the 8 DTVP-2 subcategories for ASD

ASD correlations											
Variables	**ManDex**	**AimCatching**	**Balance**	**EHc**	**PinSP**	**Cop**	**FG**	**SpR**	**VC**	**VMSp**	**FC**
1.Manual dexterity	-										
2. Aim Catching	0.20	-									
3. Balance	0.67 **	0.21	-								
4. EHc	0.43 *	0.04	0.37 *	-							
5. PinSP	0.10	0.14	0.11	0.32	-						
6. Cop	0.66	0.31	0.68 **	0.36	0.20						
7 FG	0.35	0.15	0.24	0.18	0.35	0.35	-				
8 SpR	0.46	0.43*	0.54 **	0.50**	0.19	0.56**		-			
9 VC	0.44	0.05	0.33	0.23	0.37	0.35	0.68**	0.08	-		
10. VMSp	0.41	0.29	0.41*	0.61**	0.32	0.53**	0.27	0.66**	0.25	-	
11. FC***	0.26	0.18	0.21	0.20	0.48**	0.17	0.46*	0.16	0.51*	0.24	

* p < .05, ** p < .001 ***correlations with this variable were made using the Spearman method

Table 3 Correlation between the three M-ABC dimensions and the 8 DTVP-2 subtypes for ADHD

ADHD correlations											
Variables	ManDex	AimCatching	Balance	EHc	PinSP	Cop	FG	SpR	VC	VMSp	FC
1.Manual dexterity	-										
2. Aim Catching	0.33	-									
3.Balance	0.52**	0.36	-								
4. EHc	0.24	0.01	0.10	-							
5. PinSP	-0.02	0.06	-0.27	0.08	-						
6. Cop	0.45*	0.31	0.36*	-0.10	-0.15	-					
7 FG	0.19	-0.22	0.13	-0.05	0.11	0.18	-				
8 SpR	0.30	-0.02	-0.14	0.15	0.21	0.17	0.36 *	-			
9 VC	0.20	0.25	0.11	-0.16	0.11	0.15	0.5*	0.30	-		
10. VMSp	0.57*	0.26	0.21	0.23	-0.01	0.47 *	0.13	0.34	0.09	-	
11. FC***	0.13	0.21	0.01	-0.05	0.25	0.22	0.17	0.39	0.24	-0.12	-

* p < .05, ** p < .001 ***correlations with this variable were made using the Spearman method

For the values that showed statistically significant correlations, the following multiple linear regressions were performed. Using the backward elimination method, it was found that the variables Manual Dexterity (B=.64, *p*=.146) and Balance (B=.94, *p=0*.029) predicted the performance of children with ASD in VMI (R^2_{adj} =.41, F(2,27)=10.94, *p*<.001). Deeper, performance in Manual dexterity (B=.17, *p=0*.021). and Balance (B=.15, *p=0*.047) predicted the performance of children with ASD in the Copying subcategory ($R^2_{adj=}$.53, F(2,27)=15.37, *p*<.001). Furthermore, it was found that only performance in Manual dexterity (B=.16, *p=0*.019) predicted performance in Visual-Motor Coordination ($R^2_{adj=}$ .15,F(1,28)=6.20, *p*=.019), while only performance in Balance (B=.17,*p=0*.025) predicted performance in Visual-Motor Speed (R^2_{adj} =.14, F(1,28)=5.58, *p*=.025).

Similarly, using the sequential subtraction method, the Manual dexterity variable (B = .67, *p* = .007) was found to predict the performance of children with ADHD on the VMI (R^2_{adj} = .21,F(1,28)=8.45, *p* = .007). Going deeper, performance on Manual dexterity (B = .15, *p* = .014) predicts performance of children with ADHD on the Copying subcategory (R^2_{adj} = .17, F(1,28) = 6.94, *p* = .014).

Finally, to investigate differences in DTVP-2 performance and its subcategories between ASD and ADHD children, no statistically significant differences in visual perception performance were observed. In contrast, in Movement ABC-2 performance, the performance in the Balance category of children with ASD (*M = 17*.33, *SD = 8*.77) was found to be significantly lower (t(58) = -3.63, *p* < .001) compared to the performance of children with ADHD (*M = 25*.22, *SD = 7*.07) (Figure 1).

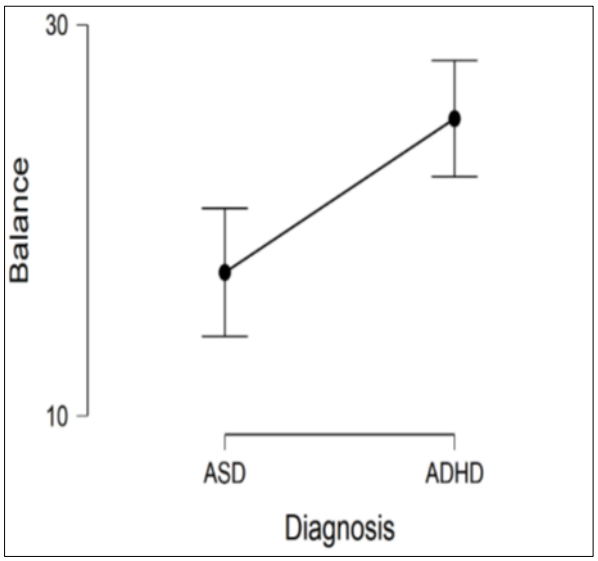

Figure 1 Comparison of ASD- ADHD performance in category M-ABC2 "Balance"

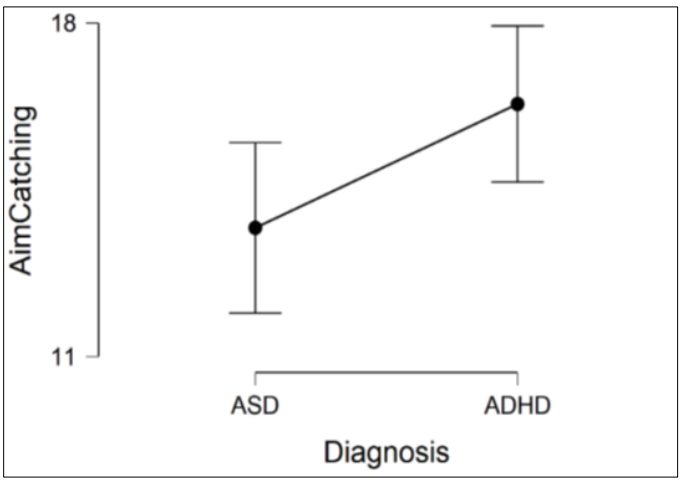

Figure 2 Comparison of ASD- ADHD performance in category M-ABC2 "Aiming and catching

Furthermore, the performance in the Aiming & Catching category of children with ASD (*M=13*.7, *SD=4*.8) compared to the performance of children with ADHD (*M=16*.3, *SD=4*.39) was found to be significantly lower (t(58)= -2.19, *p=.* 032) (Figure 2).

4. Discussion

The aim of the present study was to investigate the relationship between motor function and visual perception in school-aged children with neurodevelopmental disorders. The findings indicated statistically significant correlations between Movement ABC-2 total score and the three categories of the DTVP-2. Consistent with the results of Tepeli's (2014) [3] research, the hypothesis of a relationship between the two domains was strengthened, demonstrating that high or low performance on the total score and performance on the individual categories of the visual perception tool was significantly correlated with high or low performance on the total score and individual categories of the motor function tool, respectively.

Focusing on the motor function and visual perception skills, manual dexterity and balance showed correlations with all subcategories of visual perception skills in the visual-motor integration category (eye hand coordination, copying, spatial relations, visual-motor speed). Upon further investigation of the relationships between the two skills, it was found that performance in manual dexterity predicted performance in the visual-motor integration category, specifically performance in visual-motor coordination and copying. Furthermore, performance in balance was found to predict performance in copying and visual-motor speed. The above analyses are consistent with similar findings by Klein et al. (2010) [16], supporting the notion of a direct relationship between the child's fine motor skills, eye-hand coordination and copying, pointing out the contribution of this relationship to the development of handwriting performance in the areas of writing speed and letter formation. The research findings equally highlight the relationship between eye-hand coordination and balance, which serves as a critical factor in a child's development and achievement of postural control (Şimşek & Şimşek, 2020) [17]. The close connection between visual-motor coordination and postural control aims to ensure the accuracy of performing motor actions, such as handwriting performance on a task surface, (Flatters et al., 2014) [18]. Therefore, deficits in postural control or motor deficits are associated with difficulties in processing information in space, which appear to improve in parallel following visual-focused interventions for children with ASD (Kaplan, 2005) [19]. Similarly, in the group of children with ADHD, moderate correlations were found between the manual dexterity category and the VMI and GVP categories of visual perception, specifically in the subcategories of copying and visual-motor speed. Upon further investigation using a multiple linear regression model, it was found that ADHD children's performance in manual dexterity predicted performance in the visual-motor integration category, specifically in the copying skill. The above findings support the hypothesis of Germano et al. (2013) [20] regarding the existence of visual-motor integration deficits and their relationship with low handwriting performance, which is due to both fine motor deficits in children with ADHD and visual perception skills.

The present study, however, focused on looking for possible differences in performance on the two functions between groups. The results of this hypothesis indicated statistically significant differences between ADHD and ASD with respect to the motor function M-ABC2 categories, aiming/ catching and balance. Specifically, children with ADHD performed better in the above categories compared to children with ASD. The findings of the reported analysis are in strong agreement with the study by Ament et al. (2015) [21], who argued that the observed greater motor function deficits in children with ASD are comparable to the deficits of children with ADHD, particularly in the aiming/catching and balance categories. Contrary to the above results, analysis to find differences between the two groups in terms of visual perception did not reveal statistically significant differences between performances. The similar way in which children with ADHD and ASD appeared to respond is likely due to the view that difficulties in visual perception may arise from dysfunction in the dual model of movement-visual perception, as secondary co-occurring deficits of the neurodevelopmental disorder (Crawford et al., 2008; Piek & Dyck., 2004; Neilson & Neilson., 2004) [22][23][24].

The limitations that emerged during the conduct of the research are identified at the level of methodological weaknesses. First, it is a retrospective chart review study. Second, psychometric properties of the occupational therapy assessment tools are not available for the Greek population of typically developing children and children with neuro-developmental disorders. In addition, older versions of the assessment instruments (DTVP-2) were available for the study (Hammil, Pearson & Voress, 2014) [25].

Prospective follow-up studies would clearly provide further insights into the functioning of the movement-visual perception relationship and the factors that mediate the relationship over time.

5. Conclusion

The findings of the present study highlight the relationship between motor function and visual perception as it is manifested in children with ASD and ADHD at school age. However, it highlights the need for further research activity in the future on the association between the two functions in relation to the quality of children's performance in a variety of domains of functioning beyond academic achievement, such as self-care, socializing and play. Furthermore, studying the association between the two skills in a wider range of disorders would provide more information about functioning.

In-depth knowledge of how motor function relates to visual perception offers valuable opportunities, therapeutically and research-wise, to enhance children's participation in daily occupations related to skills such as writing. The relationship between motor- visual perception deficits underlines the need for early detection and intervention in these skill areas of children with a neurodevelopmental disorder. Identifying these deficits in children with neurodevelopmental disorders, assessing their impact on functioning and selecting evidence-based intervention programs to address them could contribute to the improvement of their quality of life.

Compliance with ethical standards

Disclosure of conflict of interest

The Authors proclaim no conflict of interest.

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