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COGNITION AND FINE MOTOR SKILLS IN AUTISM SPECTRUM DISORDERS

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ABSTRACT

BACKGROUND: Children with autism spectrum disorder (ASD) primarily present with social impairments but also exhibit notable physical characteristics such as motor delays and deficits that influence their daily functioning. The execution of smooth, controlled, and purposeful movements depends on the integrated operation of sensory inputs, cognitive processing, and coordinated cerebral functions. In children with ASD, reduced cognitive functioning may disrupt this integration and may adversely affect the development of fine motor skills (FMS). This study aims to examine the relationship between cognitive functioning, FMS and the level of adaptive functioning in children with ASD.

MATERIALS AND METHODS: This cross-sectional study included 65 children with ASD, aged 3 to 4 years, who met the specific inclusion criteria. Participants were recruited from Vidyasudha – centre for Children with Special Needs at Sri Ramachandra Institute of Higher Education and Research. Diagnosis of ASD was confirmed using the Childhood Autism Rating Scale (CARS). Fine motor skills were evaluated with the Peabody Developmental Motor Scales, Second Edition (PDMS-2), while cognitive and adaptive functioning were assessed using the Developmental Assessment of Young Children, Second Edition (DAYC-2).

RESULTS: FMS showed poor performance whereas cognitive functioning showed very poor performance. ANOVA revealed significant difference in FMS between very poor and poor cognitive levels and very poor and below average cognitive levels at p value <0.05. ANOVA showed significant difference in FMS at different adaptive levels at p value <0.05 conveying that FMS has a significant impact on the adaptive skills of children with ASD.

CONCLUSION: Cognitive deficits have a direct impact on FMS, which in turn affect adaptive behavior in children with ASD. The findings of this study underscore the importance of pediatric therapists individualizing interventions according to each child's cognitive profile; cognitive deficits should be assessed and addressed concurrently while training FMS and activities of daily living to optimize outcomes for children with ASD.

Key Words: Fine motor skills, Autism, Cognition, Adaptive functioning, PDMS

INTRODUCTION:

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by cognitive and behavioral impairments of varying degrees and represents a significant public health challenge. According to World Health Organization, the global prevalence of ASD was estimated as approximately one in 127 children in 2021. A prevalence rate of 62/10000 worldwide with substantial increase and high variability of prevalence over the continents after 2010 has been reviewed (Elsabbagh et al., 2012; Chiarotti and Venerosi., 2020). Although the

global awareness of ASD has improved, there are major challenges in accurate diagnosis, accessing appropriate therapy and determining true prevalence especially in developing countries (Oyama A. Y et al., 2017).
Sensorimotor dysfunction is found to be an intermediate phenotype in children with ASD who show abnormal patterns of motor learning and sensorimotor integration due to altered cerebellar connectivity (Stoodley et al., 2017). ASD is classified as neurodevelopmental psychiatric disorder according to Diagnostic and Statistical Manual 5 (DSM 5 criteria) but physical features, particularly motor impairments are recognized as associated symptoms which are presented with delays and deficits. Eighty-eight percent of children with ASD are at risk for motor impairment with a relative risk 22.2 times higher than that of the general population which increases with poor social communication, cognitive and functional impairment (Bhat., 2021). Clinically children with ASD frequently exhibit hypotonia, motor apraxia, reduced ankle mobility, delays in gross and fine motor skills, toe-walking, and challenges in postural control (Ming et al., 2007; Minshew et al., 2004; Kindregan et al., 2015).
Gross and fine motor skills (FMS) are delayed in children with ASD and were similar to those of children with developmental delay which demands complete developmental evaluation including motor functioning (Provost et al., 2006). Children with ASD experience an average delay of 6 months in gross motor skills and 8 months in FMS (Lane et al., 2012). Gross motor deficits improve over time allowing the child to gain motor independence by the time they reach for professional intervention but fine motor deficits continue and interfere with activities of daily living (ADL), thereby hindering the overall development. An average eight-month delay in FMS during the first two years of life has been identified as a significant predictor of autism severity (MacDonald et al., 2014).
Motor and cognitive skills mature along a similar trajectory and are closely related to each other where delay or deficit in movement may influence cognitive development while impaired cognitive function may affect motor skills which shows that they are interdependent.
Impairments in attention are the most reported cognitive deficits which is spread across many domains including selective, sustained and spatial attention. Seventy six percent of children with ASD show marked fluctuations in performance on intelligence measures and these children have unpredictable cognitive heterogeneity (Mandy et al.,2015). Children with ASD face challenges in orienting attention accurately and rapidly according to the need of task, position in space and continuous change in environment which becomes a disadvantage in their learning. (Allen., 2001).
Cognitive deficits place these children with limited motor skills and these in turn, affect the adaptive functioning of the child which includes behaviours critical for independent living such as daily living skills, social competencies and communication abilities. Longitudinal studies of adaptive behaviour in children with ASD showed persistent impairment which did not improve over time and low processing speed in cognitive functions significantly correlated to adaptive functions (Pugliese et al., 2015; Hedvall et al., 2013).
Cognitive recognition of an object is required for an effective FMS execution but deficits are seen predominantly on attentional processes which could prevent the child from focusing and decision making. This in turn could have an impact on the planning and executive component thereby affecting the fine motor performance. FMS which is inevitably required for specific activities of daily living, when found to be decreased could have an impact on adaptive function of the children with ASD which demands the need of the study.

AIM: To explore the level of cognitive functioning and its impact on FMS and adaptive functioning in children with ASD.

MATERIALS AND METHODS

Subject Recruitment: This cross sectional study was conducted in Vidyasudha – School for children with special needs, Sri Ramachandra Institute of Higher Education and Research after receiving approval from institutional Ethics committee (IEC/NI/14/JAN/38/11). The study included 65 children aged 3-4 years of both genders, diagnosed as ASD based on Childhood Autism Rating Scale (CARS). Subjects with associated attention deficit and hyperactivity disorder, upper limb musculoskeletal injuries and with visual and auditory impairments were excluded. All procedures adhered to the ethical standards outlined in Helsinki declaration as well as institutional and national research guidelines.

INSTRUMENTATION

PEABODY DEVELOPMENTAL MOTOR SCALES-2

The Peabody Developmental Motor Scales - Second Edition (PDMS-2) consists of six subtests that measure interrelated abilities in motor development. It was designed to assess gross and FMS in children from birth through six years of age. It consists of 6 sub test measures – Reflexes, Stationary, Locomotion, Object manipulation, Grasping and Visual motor integration. Grasping and Visual motor integration sub test contribute for the Fine Motor Quotient (FMQ) score and entire six components of PDMS-2 subtests contribute to a Total Motor Quotient (TMQ) which is the best estimate of overall motor abilities.
Grasping subtest assesses the ability of a child to use his or her hands to hold an object with one hand and controlled use of the fingers progressing to bimanual activities. Visual-motor integration subtest assesses the

ability of a child to perform tasks involving coordination of eye and hand using his or her visual perceptual skills such as reaching, grasping and manipulating an object.

DEVELOPMENTAL ASSESSMENT FOR YOUNG CHILDREN – DAYC- 2:

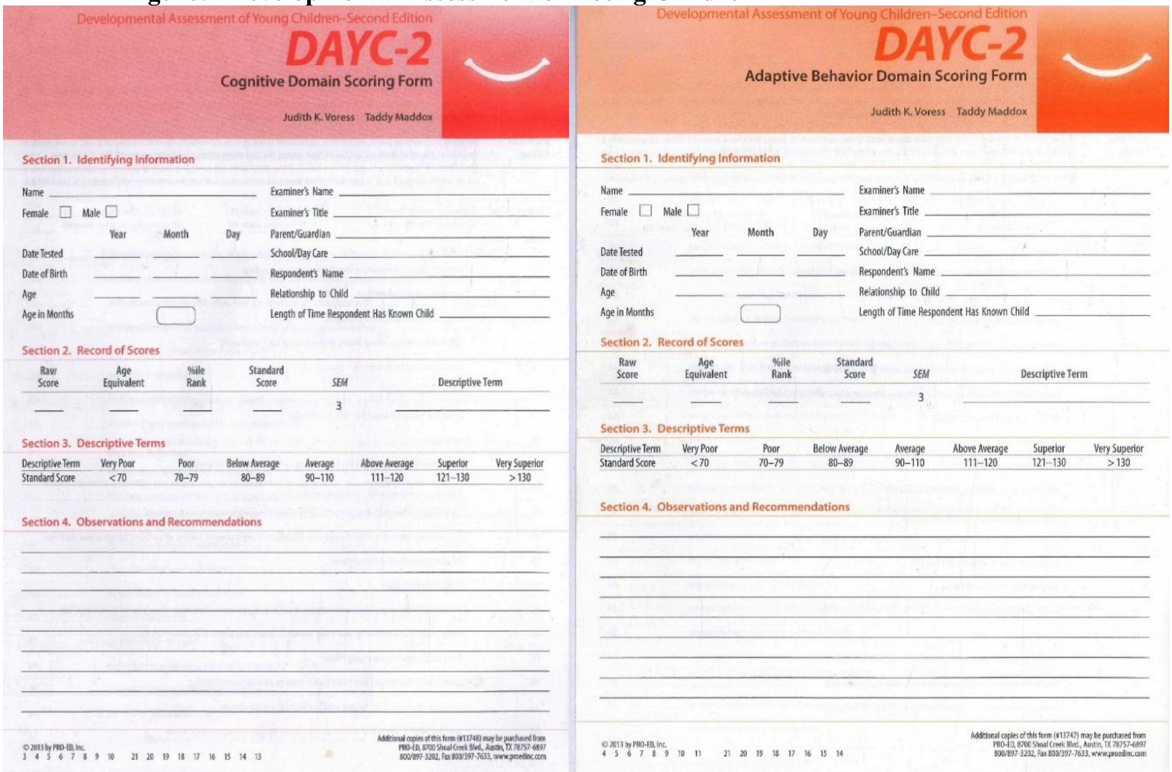
Cognitive and adaptive functions were measured with Developmental assessment for young children (DAYC-2). This test measures the child from birth through 5.11 years in five domains: cognition, communication, social-emotional development, physical development, and adaptive behavior. All five domains can be assessed together or the domains of interest can be measured independently. Domain reliability coefficients for the group range from .70 to .91 (Swartzmiller et al., 2014). Child's abilities are examined through observation, interview of caregivers and direct assessment. The cognitive domain contains 88 items and adaptive behaviour domain contains 64 items. Each item is either scored 1 or 0 based on their performance and basal is attained on three consecutive scores of 1. Raw score is converted into age equivalent and standard scores are taken for analysis in this study.

PROCEDURE

Children diagnosed as ASD by the developmental pediatrician and clinical psychologist using CARS were included who met the criteria after obtaining informed consent from their parents or caretakers. Gross and fine motor development were assessed following the standardized procedures outlined in the PDMS-2 manual. Age-appropriate items were administered for each subtest, and raw scores were calculated accordingly. These raw scores were then converted into age equivalents, percentiles, and standard scores. Gross Motor Quotient (GMQ) and Fine Motor Quotient (FMQ) were derived by summing the standard scores of their respective subtests. Motor development was ranked as very superior, superior, above average, average, below average, poor and very poor. Adaptive behavior and cognitive ability were assessed with Developmental assessment for young children – DAYC- 2. Raw score was converted into age equivalent and standard score which was interpreted accordingly.

Figure:1 Peabody Developmental Motor Scale 2

Figure:2 Developmental Assessment of Young Children 2


Developmental Assessment of Young Children–Second Edition
DAYC-2
Cognitive Domain Scoring Form
Judith K. Voress Taddy Maddox

Section 1. Identifying Information
Name
Female ☐ Male ☐
Year Month Day
Date Tested
Date of Birth
Age
Age in Months
Examiner's Name
Examiner's Title
Parent/Guardian
School/Day Care
Respondent's Name
Relationship to Child
Length of Time Respondent Has Known Child

Section 2. Record of Scores

Raw Score	Age Equivalent	%ile Rank	Standard Score	SEM	Descriptive Term
				3	

Section 3. Descriptive Terms

Descriptive Term	Very Poor	Poor	Below Average	Average	Above Average	Superior	Very Superior
Standard Score	<70	70–79	80–89	90–110	111–120	121–130	>130

Section 4. Observations and Recommendations

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Developmental Assessment of Young Children–Second Edition
DAYC-2
Adaptive Behavior Domain Scoring Form
Judith K. Voress Taddy Maddox

Section 1. Identifying Information
Name
Female ☐ Male ☐
Year Month Day
Date Tested
Date of Birth
Age
Age in Months
Examiner's Name
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Section 3. Descriptive Terms

Descriptive Term	Very Poor	Poor	Below Average	Average	Above Average	Superior	Very Superior
Standard Score	<70	70–79	80–89	90–110	111–120	121–130	>130

Section 4. Observations and Recommendations

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RESULTS: 54 male and 11 female children participated in this study where 63 children were right handed and 2 children were ambidextrous. ANOVA was used to find the difference in FMS at different cognitive levels which showed a significant difference in score between very poor and poor cognitive levels and very poor and below average cognitive levels at p value <0.05 (Table:3). ANOVA was used to find the difference in FMS at different adaptive levels which showed significant difference at p value <0.05 conveying that FMS has a significant impact on the adaptive skills. (Table: 5)

Table 1: Demographics of study participants (N=65) and mean values

FACTORS		MEAN (SD)
AGE (37-48 months)		42.89 (3.21) months
GENDER		M/C- N= 54, F/C- N= 11
CARS	Mild to Moderate - 53 Severe - 12	34.59 (1.84)
BMI		16.79 (1.54)
HANDEDNESS		Right -63 Ambidextrous -2
FINE MOTOR QUOTIENT (N=65)		69.69 (9.573)
GROSS MOTOR QUOTIENT (N=65)		80.06 (9.76)
COGNITION		68.75 (7.59)
ADAPTIVE BEHAVIOUR		70.61 (7.06)

Table:2 Different levels of Cognitive functioning and FMQ

	MEAN (SD)	DIFFERENT LEVELS -COG MEAN (SD)	FMQ

COGNITIVE FUNCTIONING	N=65 69.09 (8.03)	very poor N=29	61.89 (5.57)	63.48 (9.95)
		poor N=31	73.77 (2.91)	74.06 (5.50)
		below average N=5	81.8 (1.78)	78.6 (6.42)

COG- Cognition FMQ- Fine motor quotient

Figure:3 Different levels of Cognitive Functioning and FMQ

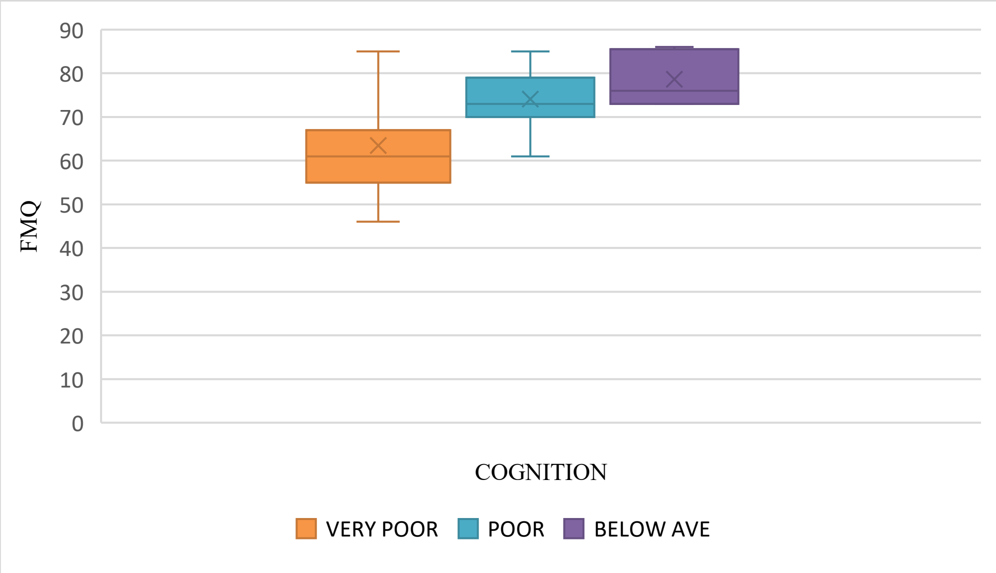

Table:3 Comparison of FMQ at different Cognitive levels

	Very poor COG Mean (SD) N= 29 T1	**Poor COG Mean (SD) N=31 T2**	**Below average COG Mean (SD) N=5 T3**	**F**	**p value**
FMQ	63.48 (9.95)	74.06 (5.50)	78.6 (6.42)	16.96	0.001
Mean Difference	T1 – T2 (a)	T2-T3 (b)	T1-T3 (c)	0.001 (a,c)	
	10.58	4.54	15.12		

COG- Cognition FMQ- Fine motor quotient ANOVA Significance at $p< 0.05$ Post Hoc Analysis $p< 0.05$
a = T1- T2 Difference in FMQ score between very poor and poor cognitive functioning
b = T2- T3 Difference in FMQ score between poor and below average cognitive functioning
c = T1- T3 Difference in FMQ score between very poor and below average cognitive functioning

Table:4 Different levels of Adaptive Behaviour and FMQ

	MEAN (SD)	**DIFFERENT LEVELS -AF MEAN (SD)**		**FMQ**
ADAPTIVE BEHAVIOUR	N=65 71.06 (7.68)	Very poor N=23	62.95 (5.62)	60.34 (7.18)
		Poor N=35	74.14 (3.15)	73.51 (5.97)
		Below Average N=7	82.28 (1.88)	81.28 (4.95)

AF- Adaptive functioning, FMQ- Fine motor quotient

Figure:4 Different levels of Adaptive Behaviour and FMQ

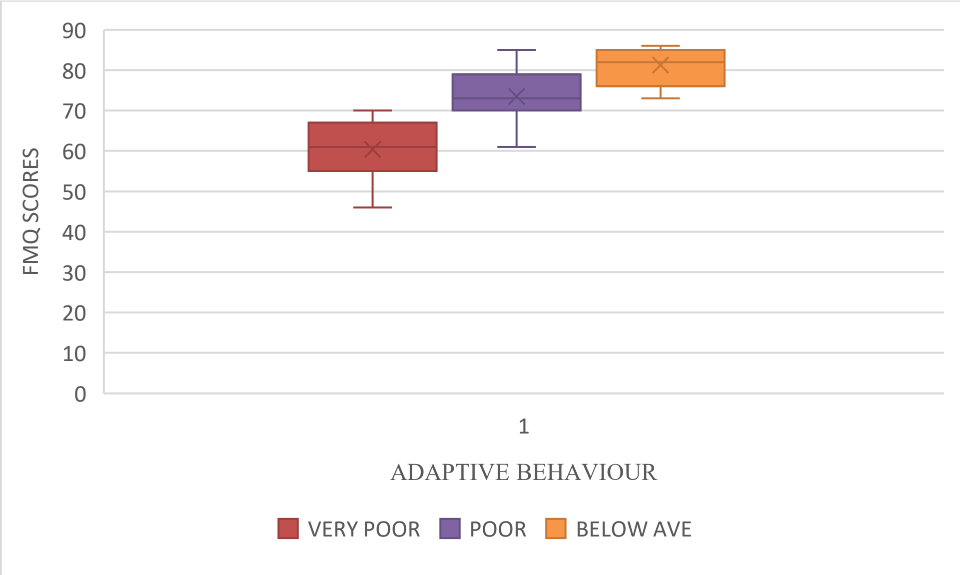

Table:5 Comparison of FMQ of different Adaptive behaviour levels

	Very poor AF Mean (SD) N= 23 T1	Poor AF Mean (SD) N=35 T2	Below average AF Mean (SD) N=7 T3	F	p value
FMQ	60.34 (7.18)	73.51 (5.97)	81.28 (4.95)	42.95	0.001
Mean Difference	T1 – T2 (a)	T2-T3 (b)	T1-T3 (c)	0.001 (a,b,c)	
	13.17	7.77	20.94		

AF- Adaptive functioning, FMQ- Fine motor quotient,
ANOVA Significance at $p < 0.05$ Post Hoc Analysis $p < 0.05$
a = T1- T2 Difference in FMQ score between very poor and poor adaptive functioning
b = T2- T3 Difference in FMQ score between poor and below average adaptive functioning
c = T1- T3 Difference in FMQ score between very poor and below average adaptive functioning

DISCUSSION:

Motor skills that develop in infancy and beyond are not simply randomly generated in the central nervous system rather the movements which are purposeful and conscious are attained by learning. When novel motor skills are produced by a child, pre-planning as well as anticipating the outcomes of the movements require cognitive development. Fine motor activities require sustained focus and attention which are often disrupted in children with ASD due to sensory processing abnormalities that may be slow, inconsistent or atypical.

The level of gross and FMS assessed with PDMS 2 in this study showed decreased skills with mean GMQ of 80.06 ± 9.76 denoting a below average performance and mean FMQ of 69.69 ± 9.57 denoting a poor performance. The mean score of cognitive function is 68.84 which denotes poor function which is consistent with the study done by William Mandy (2015) where 76% of the sample showing marked fluctuations in performance on the Weschler Intelligence Scale for Children -IV, showing unpredictable cognitive heterogeneity. As the levels of cognitive function improves, FMS increases which is evident by significant difference in FMS at different cognitive levels (very poor, poor and below average) conveying that cognitive functions are inevitably associated with motor functions. Tzu-Ying Yu et al., (2018) showed that intelligence quotient discrepancy was found to demarcate different levels of FMS in young children with ASD and better visual–motor coordination correlated with higher performance intelligence quotient. Dexterity skills inevitably require visuomotor integration (VMI) which in turn is affected by cognitive ability as supported by the study done by Ryan R Green (2016) which shows an association of VMI and cognitive ability in children with ASD.

Philipp Martzog et al, (2012) established relations between FMS of preschool children and cognitive abilities which showed a unique link between dexterity with attention and reasoning components and FMS supporting environmental interactions like eye hand coordination are strongly related to cognitive abilities than those which do not support environmental interactions like fine motor speed. Motor and cognitive skills develop along parallel trajectories with motor performance showing significant associations with specific cognitive functions (Renske

Wassenberg et al., 2005). Motor and cognitive development have symbiotic relationship and therefore delay in cognitive skills will interfere with motor skills and vice versa where both can be improved with appropriate motor intervention programs in children with ASD.

Adaptive behaviour of an individual reflects his cognitive skills by the way he applies in real life situations which includes daily living skills, social skills and communication skills. Children with ASD show decreased adaptive functioning as shown by Simonetta Panerai et al., (2014) & Corey E et al., (2011). Mean adaptive behaviour score was 70.61 which denotes poor adaptive function. This is consistent with the study done by Martina Franchini et al 2018 where significantly low performance of adaptive functioning was seen and those with high severity levels exhibited faster declining trajectories compared with typically developing children. Daily living skills such as personal hygiene, grooming and feeding make a person independent which demand more dexterity skills but these skills are significantly delayed and show slower development as observed in a study done by Vanessa Hus Bal et al., (2015) in 2-21 years of age which makes a child with ASD dependent.

Significant increase in adaptive functioning levels was evident with increase in FMS in this study conveying that FMS plays a vital role in adaptive functioning involving daily living skills making a person independent. This finding is consistent with the study done by Megan MacDonald et al., (2013) where FMS and autism severity were more predictive of adaptive skills than gross motor skills. Manual dexterity scores were associated with overall adaptive behaviour and directly with daily living skills component which clearly indicates the need of FMS for optimal adaptive behaviour as studied by Nicholas E Fears et al., (2022).

Decreased motor skills may not only impede or reduce functional ability of a child but also the overall adaptive behaviour which in turn influences the quality of life as shown by Heather C. Karras et al., (2018) where children with developmental coordination disorder showed decreased health related quality of life both in physical and psychological domains. Unaddressed motor issues in autistic children may additionally impact their mental health by lowering self-esteem and increasing self isolation. Cognitive sub domains were not analysed which could act as limitation of the study.

CONCLUSION

The study concludes that cognitive deficits have a direct impact on FMS and subsequently influence the adaptive behavior of children with ASD. These findings strongly suggest that pediatric therapist should design and individualize therapeutic programs based on cognitive levels which should be considered and addressed concurrently when training FMS and activities of daily living to achieve optimal functional outcomes in children with ASD.

DECLARATION: The authors have no conflict of interest

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