

The association of numeracy skills with Penn Conditional Exclusion Test performance of 5-to-8-year-old Turkish children

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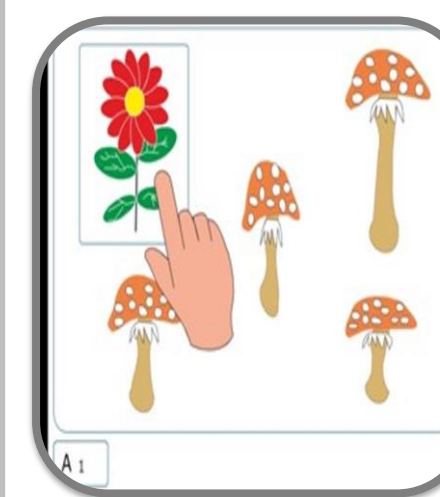
- Card sorting tests are commonly used to evaluate individual differences in task shifting abilities and are composed of multiple components such as concept formation, perseveration and set maintenance.
- Each component follows a unique developmental trajectory and is shaped by the individual differences in various capacities, including some non-EF variables such as basic numeracy skills (the understanding of patterns, relations, and relative quantities).
- Previous research stated that the use of number as a sorting criterion in card sorting tests makes the tasks more or less difficult for preschool children, and thus the suitability of some of these tests for younger children is questionable (Prevor & Diamond, 2005).
- Consistent with this argument, Söğüt et al (2021) reported that numeracy skills (comparison, classification and estimation) predicted concept formation scores only for 5-year-olds as measured by Wisconsin Card Sorting Test, which includes number as a sorting rule.
- **However, whether the predictive role of basic numeracy skills exists for the tasks without a number criterion is yet to be tested.**
- Penn Conditional Exclusion Test (PCET) measures the executive functions of abstraction and mental flexibility and does not include number as a sorting criterion. It assesses the ability to derive principles and concepts from feedback, as well as the ability to detect and adjust to changing rules (Kurtz et al., 2004).
- **The purpose of the current study** was to examine (1) the association of numeracy skills with EF-related abilities as measured by the Penn Conditional Exclusion Test (PCET) and (2) age differences in the performance of PCET subcomponents. Based on the findings of Söğüt et al (2021), we expected numeracy skills to predict only concept formation scores and age differences to be salient in the concept formation factor only for preschool children.

Method

Participants and procedure

The sample consisted of one hundred and fourteen (54 girls) Turkish children between the ages of 5 and 8. We categorized the sample into three age groups as 5-year-olds (M=5.6, SD=3.23), 6-year-olds (M=6.6, SD=3.69), and 7-year-olds (M=7.7, SD=4.08). All of them completed the PCET and ENT in a quiet room of their schools with a counterbalanced order.

Measures



✓ **Early Numeracy Test (ENT)** is a task-oriented test which measures the level of early mathematical competence of preschoolers, first and second graders. The test consists of nine components: comparison, classification, one to one correspondence, arranging, using numerals, synchronous and shortened counting, resultative counting, applying knowledge of numbers and estimating.



✓ **PCET** is a computerized test battery where participants must decide what object out of four objects does not belong to the other three. There are **three criteria** given in standard order for choosing an object: **line thickness, shape, and size**. The criterion change is based on achieving 10 consecutive correct answers for each principle.

Results

Table 1. Principal Components Analysis of the PCET

PCET Variables	Factor	
	1. Concept Formation	2. Perseveration
Correct Responses	.539	.618
Categories Achieved	.963	.145
Perseverative Errors	.077	.977
Perseverative Responses	.087	.976
Incorrect Responses	-.537	.837
Accuracy	.998	-.081
Efficiency	.991	-.056
Variance Proportion	52	41
Eigenvalue	3.63	2.885

Results revealed a two-factor structure: concept formation and perseveration

Table 2. The results of Post-Hoc Bonferroni Analyses for the PCET

PCET	5 and 6 Years		6 and 7 years		Post-Hoc (Bonferroni)	
	Mean	S.D	Mean	S.D	5 and 6 Years	6 and 7 years
CR	-13.16	3.42	-1.84	3.53	.001**	1.000
ER	13.08	3.77	3.92	3.90	.002**	.953
CAT	-1.43	.25	-.15	.25	.000**	1.000
CAT1_TR	7.85	3.20	-4.44	2.45	.050	.224
PER_ER	-2.68	2.36	1.14	2.45	.777	1.000
PER_RES	-2.95	2.57	.93	2.66	.761	1.000
ACC	-1.34	.22	-.18	.22	.000**	1.000
EFF	-.13	.02	-.01	.02	.000**	1.000

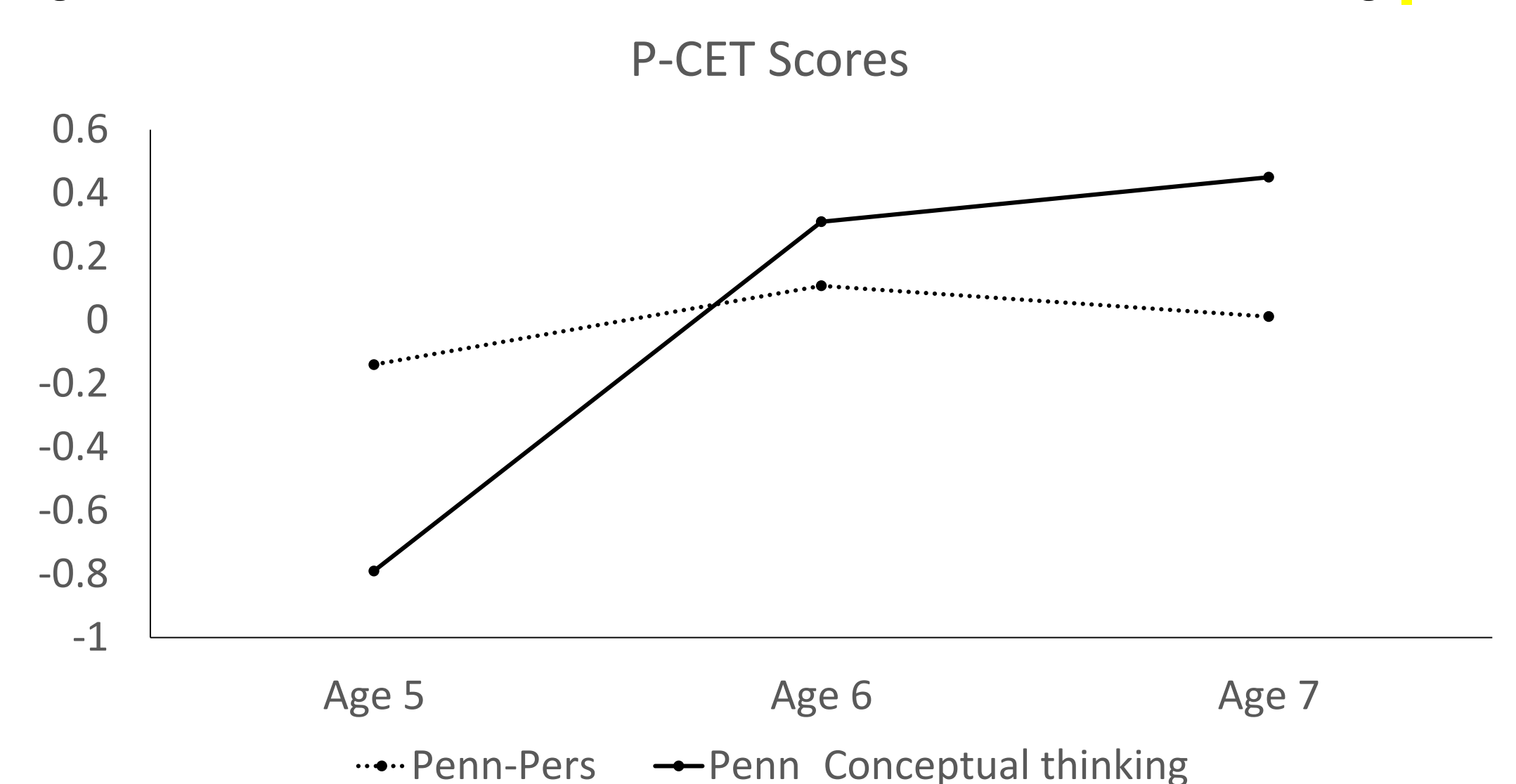
Note. CR: Correct Responses, ER: Incorrect Responses, CAT: Number of Categories Achieved, CAT1_TR: Number of Trials in PCET Using Sorting Principle 1, PER_ER: Perseverative Errors, PER_RES: Perseverative Responses, ACC: Accuracy, EFF: Efficiency

Table 3. Hierarchical Regression Analyses for the PCET Scores

PCET Scores	B	S.E-B	B	t	p	Rsquare	Fchange
Concept Formation							
Step 1					.000**	.26	6.3
Demographics							
Age	.37	.17	.32	2.13	.035*		
Step 2					.000**	.47	4.24
ENT Variables							
Comparison	.46	.15	.25	3.01	.003*		
Classification	.17	.078	.20	2.23	.028*		
Perseveration							
Step 1					.132	.09	1.68
Demographics							
Step 2					.476	.16	.96
ENT Variables							

Two ENT scores (comparison and classification) predicted the concept formation factor of the PCET; indicating a significant relationship between the PCET performance and numeracy skills in terms of concept formation.

Figure 1. The Standardized Bartlett scores of CF and PSV as a function of age



Only concept formation scores improved significantly between the ages of 5 and 6, but this trend became less pronounced after the age of 6.

Discussion

- **The significant association of numeracy skills only with the PCET concept formation performance** might be explained by the fact that both tasks require conceptual thinking ability in common.
- ✓ Firstly, regarding the PCET, it is difficult to understand whether the performance is related with the conceptual knowledge or mental flexibility itself when complex sorting criteria such as shape, size and density is included, especially for the children between ages of 5 to 6. Earlier research found that prior difficulty of the rules is one of the factors affecting the performance of preschool children in EF tasks (Deák, 2003). Thus, the present study supported the finding that children's ability to comprehend and make use of the task rules affect their overall flexibility in a test.
- ✓ Likewise, numerical competence (particularly, comparison and classification) requires the use of conceptual thinking capacity, since the essence of mathematics is dependent on concepts and relationships as well as symbols (Jovanova-Mitkovska, 2014). Thus, from this point of view, it is not surprising that the ENT scores only predicted the Concept Formation scores of the PCET.
- **Regarding the age differences**, the present study revealed that 5 to 6 years of age is the period when a significant improvement occurs for this specific sample of children.
- ✓ This finding is in line with earlier studies showing that the ability to generate concepts and classify objects appears between the ages of 3 and 4, these abilities manifest a significant progress around the ages of 4 and 5, which enables children to observe two sorting criteria in the same group of objects (Smidts et al., 2004). However, the ability to define a third classification criterion improves only after ages of 5 (Smidts et al., 2004).
- ✓ Therefore, the possible contribution of certain capacities such as classification and comparison should be considered when evaluating the card sorting test scores of children aged 5 to 6.

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