Modulation of general and specific cognitive precursors of early mathematical performance

Estíbaliz Aragón¹, Gamal Cerda², Manuel Aguilar¹, Carlos Mera¹, José I. Navarro¹

¹Universidad de Cádiz; ²Universidad de Concepcion

Estíbaliz Aragón

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ABSTRACT

The main goal of this study was to analyse, using structural equation modeling, the contribution of predictors of both domain-general (working memory, processing speed and receptive vocabulary) and domain-specific (estimation and magnitude comparison) processes to informal mathematical performance (numbering, comparison, calculation and understanding of concepts) in preschoolers. A total of 158 preschool students (ages ranging from 52 to 64 months) participated in the investigation. Students were assessed with informal tasks measuring mathematical thinking, numerical estimation, symbolic and non-symbolic comparison-making, coding, receptive vocabulary, and backward digit span. Results showed that a structural equation model for multiple indicators and several factors could explain informal mathematical thinking capacity in young children. The model reduced specific-domain factor effects such as magnitude comparison. In conclusion, the effect of working memory was found to be less than the straight impact of the general-domain predictors considered in the study.

GUIDELINES

Considering the characteristics of the sample and that we used six different tests, two evaluation sessions were carried out for each child. Evaluators were specifically trained to apply the instruments used. In one of the sessions, various cognitive tests (receptive vocabulary, working memory, processing speed) were administered, as well as specific tests of magnitude comparison (symbolic and non-symbolic) and the number line estimation test. In the other session, informal mathematical competence was evaluated through the TEMA-3 test. Administration of the evaluation was carried out individually, under optimal conditions of applicability. Each session's duration ranged between 30 and 45 minutes. Tests were administered following an inter-session and intra-session random delivery. The assessment was carried out during school hours; playground breaks were provided as deemed appropriate.

BEFORE START

The study was carried with the specific approval of the bioethics committee of authors' institution. The school principal, administration school team and the teachers were all informed of the purpose and nature of the study. Upon being granted permission to proceed and prior to starting the assessments, written informed consent of the parents in accordance with the Declaration of Helsinki and Singapore Statement was obtained.

MATERIALS

Test of Early Mathematics Ability - Third Edition, Informal Thinking Assessment (TEMA-3) [35]. This test assesses counting, comparison of quantities, informal calculation and understanding of basic informal concepts. The test was individually administered to each child and lasted between 30–40 minutes, according to the student's age. The informal reasoning subtest was considered appropriate for the current study, given that this domain constitutes the main source of variability in mathematical competence at the age of four years [36]. In several cases, the total score of the TEMA-3 was equivalent to the numerical subtest, without the contribution of formal thinking to the score of early mathematical competence. The Cronbach's alpha was .91.

The Numerical Estimation Task [37] is a pencil-and-paper test that evaluates students' estimation of distance on a number line. During its administration, participants are presented with a sheet of paper with a 20-centimeter number line, which starts at 0 and ends at 20. Above the line, in the upper central part of the sheet, a number is shown. Participants must point out where the number would fall along the straight line. The test consists of 10 items, which correspond to the following numbers: 2, 4, 7, 8, 11, 13, 16, 17, 18 and 19, each of which is randomly presented. The mean comparison rate is calculated according to the number of correct answers with respect to the number requested by the test versus the number provided by the student. In this study, answers were considered correct if they did not present an error rate higher than $\pm 15\%$ for the requested number. The Cronbach's alpha was .80.

The Symbolic and Non-Symbolic Comparison Test [38] is a pencil-and-paper test that evaluates students' magnitude processing abilities. The test consists of 56 pairs of items; each presents two magnitudes to be compared (range from 1 to 9). The student must select the larger of the two magnitudes. The test runs for four minutes total, allotting two minutes to solve as many elements as possible for each symbolic (56 items) and nonsymbolic (56 items) task. The Cronbach's alpha was .86.

The Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III), Coding subtest [39] is part of a comprehensive test of intelligence for preschool and primary school students up to 7 years 3 months. It assesses processing speed, visual perception, visual-manual coordination, short-term memory, learning ability and cognitive flexibility. The student must complete a set of 64 figures presented with the appropriate symbols. He/she must follow the reference models in 2 minutes or less. The Cronbach's alpha for this test was .84.

The Dyslexia Screening Test - Junior (DST-J), Receptive Vocabulary subtest [40] assesses receptive vocabulary and reasoning ability, using a multiple-choice format. The test is comprised of 18 items; each correct item scores one point. The Cronbach's alpha was .88.

The Dyslexia Screening Test - Junior (DST-J), Backward Digit subtest [40] evaluates verbal working memory. It involves the oral repetition of digits backwards. As the test progresses, the number of digits – and consequently task difficulty – increases. The task is composed of seven series of numbers; each series comprises two items. The test includes five items; two of these are administered if the child has difficulties in properly understanding the instructions. The Cronbach's alpha was .85

SAFETY WARNINGS

Not applicable

BEFORE START INSTRUCTIONS

The study was carried with the specific approval of the bioethics committee of authors' institution. The school principal, administration school team and the teachers were all informed of the purpose and nature of the study. Upon being granted permission to proceed and prior to starting the assessments, written informed consent of the parents in accordance with the Declaration of Helsinki and Singapore Statement was obtained.