Parents' Observations of Kindergartners Who Are Advanced in Mathematical Reasoning

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What behaviors and abilities do young, mathematically precocious children display? Are parents able to recognize such precocity? Questionnaires were completed by 100 parents of kindergarten-age children whom the parents thought to be mathematically precocious. Questions were derived from parents' spontaneous descriptions of the development of their children as well as behaviors consonant with items on two screening measures: the Arithmetic subtests of the Kaufman Assessment Battery for Children (K-ABC) and the Wechsler Preschool and Primary Scale of Intelligence, Revised (WPPSI-R). The children, as a group, did well on the screening measures, achieving mean scores of 121.4 (92nd percentile) on the K-ABC and 124.9 (95th percentile) on the Wechsler subscales. The questionnaire asked parents 27 items about children's mathematical behavior and 18 items comparing the children with peers on nonmathematical skills. Five factors were found to characterize the parents' responses: (a) a general intellectual factor, (b) short- and long-term memory, (c) rote (rehearsed) memory, (d) spatial reasoning, and (e) specific relational knowledge. It was concluded that parents can indeed identify young children who are advanced in mathematical reasoning and can describe that mathematical behavior in coherent ways.

Despite a considerable literature describing predictable sequences in the development of numeric problem solving by children in the primary grades (e.g., Case, 1991; Saxe, Guberman, & Gearhart, 1987; Siegler, 1991), remarkably little is known about children who develop more slowly or quickly in this domain. The literature about young children who are advanced in mathematical reasoning is, indeed, almost nonexistent (Robinson, 1993). Yet, there is a growing recognition of the domain-specific nature of development and of giftedness

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(Gardner, 1983), directing interest toward identifying children with specific talents.

Identification of Advanced Mathematical Reasoning

To date, almost all efforts at identification and encouragement of mathematical talent have focused on seventh grade and beyond. For young students who reason well mathematically and verbally, regional talent searches now involve some 160,000 seventh graders each year with academic-aptitude measures, namely, SAT and ACT. A few studies of elementary school children advanced in math (Assouline & Lupkowski, 1992; Lupkowski-Shoplik, Sayler, & Assouline, 1993; Mills, Ablard, & Stumpf, 1993) have encouraged earlier identification, and some of the regional talent searches have begun reaching out toward fifth and sixth graders by using other national exams such as the PLUS (administered by ETS) and EXPLORE (administered by ACT). Even so, there may be a sizable group of talented children for whom there occurs "math turnoff" in the primary grades. This study was directed at identifying much younger math-talented children as they enter school.

Parent Identification of Giftedness

Previous investigators have shown parents of young children to be relatively accurate in identifying giftedness in their children, considerably more accurate than kindergarten teachers (e.g., Ciha, Harris, Hoffman, & Potter, 1974). Jacobs' (1971) study was particularly dramatic. He evaluated all 654 kindergarten children in a school district and found 19 "gifted" with WPPSI Full-Scale IQs of 125 or higher. At the beginning of the year, parents nominated 26 children as gifted, 16 of whom subsequently attained test scores of at least 125; after six months with the children, teachers nominated 46, none of whose scores placed them in the original gifted group, though teachers did include two gifted children who had entered later in the year.

Parents of preschoolers have also shown themselves to be accurate identifiers of precocity. For example, Silverman, Chitwood, and Waters (1986) used a checklist to aid parents in identifying gifted young children. Of the 21 children nominated by parents, 14 attained high scores on the Stanford-Binet, Form L-M, while many of the remaining 7 had histories of chronic ear infections that may have impacted language acquisition. Colligan (1976) used the Minnesota Child Development Inventory to obtain parent observations of 59 preschool children, finding a correlation of .79 between the inventory scores and the children's later reading scores at the end of kindergarten. A 5-year longitudinal study in our own laboratory with children who had exhibited precocious expressive language as toddlers (Dale, Robinson, & Crain-Thoreson, in press; Robinson, Dale, & Landesman, 1990) further confirmed parent's accuracy in identifying early precocity in a domain-specific area, and this advanced-level competence tended to remain stable to school age.

The only previous attempt (Robinson & Robinson, 1992) to identify math-precocious preschoolers, ages 2–5, embedded that effort in a search for talent in a number of other domains and suffered from a lack of standardized measures suitable for such young children. Even so, parents' descriptions matched their children's math scores on the Peabody Individual Achievement Test to a significant degree ($r = .34$, $N = 195$). The authors concluded that accuracy of parental perception is likely to be greatest when a skill is just emerging (as does language in the second year of life or reading somewhat later) and when parents have accurate expectations of what is "normal." Indeed, there is evidence to support the conclusion that precocity identified by early parental observations and confirmed by testing is likely to be more stable than precocity identified by tests alone (Robinson & Robinson, 1992).

With regard to parents' perceptions of their young children's overall intellectual advancement, a study by Louis and Lewis (1992) is of particular interest. Of 118 parents who brought very young children (mean age 33 months) to a specialized clinic because they believed them to be "gifted," Louis and Lewis found that those describing exceptional memory, creativity-imagination, and abstract thinking actually had children with much higher IQs (mean IQ = 149) than those describing specific rote knowledge (body parts, alphabet, numbers).

The current study was therefore designed (a) to discover whether the method of parent nomination can be used effectively to locate a population of young children advanced in mathematics and (b) to explore the ways in which parents describe such children. Following Louis and Lewis, we also investigated whether higher test performance was accompanied by higher parent ratings on indices of more complex thinking rather than on items describing the products of rote memory.

Methods

Recruitment

The children in this study were engaged in the beginning phase of a two-year longitudinal project directed at discovering and nurturing early mathematical talent. Initial recruitment of subjects for the Math Trek project occurred in winter and early spring of 1993. We cast a wide net by contacting preschools and kindergartens, both private and public; meeting with teachers of Head Start and similar state-funded programs; and establishing contacts through special schools and programs already screening for highly capable participants. These efforts were supplemented by several radio interviews and newspaper articles. Teachers were encouraged to suggest the study to parents of children showing interest in and/or advanced understanding of numbers, and parents were welcome to contact us on their own. We suggested that math-precocious kindergartners might make small purchases, tell time, read speed-limit signs, read some math symbols, and spontaneously do three-step operations (e.g., $2 + 1 + 1 = 4$). As part of the nomination process, parents were also asked what evidence had led them to conclude that their child was advanced in mathematics.

Parents of 798 children made contact with study staff; 778 returned questionnaires and consent forms. Unless they had already attained a scaled score of at least 16 on a recently administered WPPSI-R (usually in conjunction with a school application), all nominated children were administered the arithmetic reasoning subtests from the K-ABC and the WPPSI-R. These were chosen because both of these measures require children to solve word problems of increasing difficulty and both are components of major intelligence tests in wide use. Age-6 children without a full ceiling on the WPPSI-R Arithmetic subtest were also administered the Arithmetic subtest of the Wechsler Intelligence Scale for Children, Third Edition (WISC-III). Of the total pool of nominees, 199 girls and 242 boys at the kindergarten level were administered the two screening measures and attained a mean score of 118.35 on the K-ABC (116.11 for girls, 120.19 for boys). Comparable scores on the WPPSI-R were 13.85 (13.57 for girls and 14.07 for boys). Sixteen children had previous WPPSI-R scores of at least 16 and were not retested.

Questionnaire Development

The reasons cited by parents for nominating their children were categorized by the first and second authors and served as the major basis for creating a questionnaire to serve as a means of identifying young children who are advanced in mathematical reasoning. Questions about behaviors consonant with skills needed to succeed at items of the Arithmetic subtests of the K-ABC and WPPSI-R were added to the parents' reasons. The final 50-item questionnaire consisted of three parts: 5 open-ended questions concerning parents' and children's interest in numbers; 27 questions regarding children's current mathematical behaviors; and 18 questions asking parents to compare their children's skills to those of other same-age children in a variety of areas such as vocabulary, listening, reading, and creative activities. The 27 math-behavior questions asking for the presence or absence of behaviors called for a response of "Yes," "?" (not sure or no opportunity to observe), or "No." For consistency, the 18 comparative questions were also formulated with a 3-point scale: "Not advanced," "Somewhat advanced," or "Very advanced." These questionnaires were mailed to the parents of the first 120 kindergartners who were scheduled for screening; appointments had been made in the order in which parents had returned the initial nominating forms.

Typical questions about math-related skills asked parents whether their children could: "Tell how fast your car is going by the speedometer," "Play a complicated game like Monopoly (no help)," and "Tell whether a nickel or dime is more money." In other areas, parents were asked to compare their child with same-age peers on behaviors such as, "Using long sentences," "Having complicated ideas," or "Reading maps."

Results

Sample Characteristics

Of the 120 questionnaires mailed out, 5 were discarded for incomplete answers; 12 were returned after analysis began; and only 3 were not returned, a rather noteworthy 97.5% return rate. The 20 children not included did not differ from the 100 in the final sample on any demographic information or test scores. The 100 children had a mean age of 74 months, comparable to the age of the total group of 457 kindergarten nominees; males constituted 60% of this sample and 55% of the total kindergarten pool. Mean education for fathers and mothers was 16 years, not significantly different from the mean of 16 years for mothers and 17 years for fathers in the total sample. Ethnic identity of the groups was very similar. Non-Hispanic Caucasians constituted 77% of this group and 76% of the total group; Asians

constituted 13% vs. 12% of the total group; African-Americans constituted 6% of both groups; other groups, 4% vs. 6%.

For this group, the mean K-ABC Arithmetic score was 121.4 (SD = 12.16); for all screened kindergartners, the mean K-ABC Arithmetic score was 118.4. Under the assumption that the WPPSI-R can fail to provide a sufficient "top" for highly capable children of this age, for the purposes of the present study, the higher of the WPPSI-R or WISC-III Arithmetic score was taken as the Wechsler score for each 6-year-old who had been given both measures. Converting the Wechsler score to the same scale as the K-ABC (M = 100, SD = 15), the mean Wechsler score was 124.9 (SD = 14.27). Comparable combined WPPSI-R/WISC-III Arithmetic scores are not available for the total group.

Open-Ended Responses

To the open-ended question accompanying the nominating forms, "What clued you in to your child's interest or ability in math?" the parents of these 100 kindergartners most frequently mentioned adding, subtracting, and multiplying; counting; interest in money, computer games, board games, and telling time; making up story problems; reading road signs; and using arithmetic workbooks. A third of the parents also mentioned the early age at which they had observed such interest.

We examined in more detail the responses of the 15 parents whose children attained the highest mean scores on the K-ABC and the Wechsler. Most of these parents also mentioned their children's early skills at counting and, later, adding and subtracting (often with regrouping). A sampling of other remarks:

> At 4 years old, he could identify all the states of the US by shape alone and place them appropriately in a puzzle without outline cues.
>
> Likes to organize collections of things and memorizes details, including numerical information, e.g., baseball cards . . . license plates.
>
> We haven't paid much attention to his mathematical ability . . . mostly because his language skills are extraordinary. He reads, at least, at a fifth grade level.
>
> At about 4½, (son) began to play with numbers (counting by 2's, 3's, 4's, etc.), timed his ability to count (31 minutes to reach

1000), distinguished between even and uneven numbers ("Some numbers don't have middles").

"Yesterday, at home, he discovered the internal shapes within various stars (a square within a four-pointed star, a pentagon within a five-pointed star, etc.)."

(Son) absorbs anything he can learn about math because, to him, it is *fun*.

When I mentioned the possibility of participating in this project, she was quite excited, remarking, "Good. I get to do some stuff that isn't plain."

At 3½, he could estimate another person's line of sight.

Using a stopwatch to time parts of a trip.

Has recently shown interest in written music—how notes and rests divide a measure.

. . . continues to ask many conceptual math questions about things like: positive/negative numbers, infinity, fractions, etc.

. . . complains that they don't do math in kindergarten.

(Daughter) is in love with math. She walks around looking for "square numbers and paladromes (sic)."

. . . discovered the Montessori math teacher's manual last spring.

She and her father had a lengthy discussion on Avogadro's number, which is now called Avocado's number. She can tell time and can write Roman numerals up to 20 easily.

. . . will multiply and divide using factors up to 10 and various combinations of numbers. All this is done in his head . . . the process is what interests him.

Statistical Analyses

For this group of 100 children, the K-ABC and Wechsler screening scaled scores were significantly related, $r = .625$. Of the 45 three-point questions, 24 (53%) were correlated significantly with at least one of the screening measures ($p < .05$), 20 of these (44%) with both. Of the questionnaire items that were not significantly correlated with either screening measure, 5 had little variability since they already had been mastered by virtually all of the children; and several in the second section of the questionnaire were not expected to relate strongly to mathematical reasoning (e.g., playing music, fine motor skills, block building, drawing).

Gender differences were found on only 4 items (playing competitive board games, making change for $1, drawing, and fine motor skills). Boys rated higher on the first two and lower on the second two.

The matrix of inter-item correlations using SYSTAT was subjected to principal component analysis with an unrotated solution. The unrotated solution was as interpretable as the varimax rotated solution, so we report the unrotated solution. The five factors with eigenvalues above 2.0 were interpreted. Because none of the remaining factors had more than two items with factor loadings greater than .4, the variance for which they were accounting was considered unique.

Factor 1 (accounting for 17.5% of the total variance) was characterized by competence in adding and in the ability to manipulate numbers in practical ways; it was also characterized by verbal competence and complex understanding and by skills involving mastery of the alphabetic symbol system (reading, writing, and spelling) and cartography. Factor 2 (7.8% of the total variance) was characterized by short-term and long-term memory skills. Factor 3 (6.6% of the total variance) was characterized by rote memory for numeric and verbal information. Factor 4 (5.6% of the total variance) was characterized by spatial skills (including empathy, possibly the ability to discern nonverbal cues). Factor 5 (4.9% of the total variance) was characterized by more relational concepts such as the relative value of a nickel and dime. Information about factor loadings of the questionnaire items is contained in Table 1. Together, the first five factors thus accounted for 42.4% of the variance in parents' responses to this questionnaire. Presumably, the remainder of the variance is attributable to measurement error and uniqueness of the items.

Correlations of factor scores on the first three factors with the screening measures, the K-ABC and Wechsler scores, was as follows, with significance levels in parenthesis. Factor 1: K-ABC .48 (.001), Wechsler .41 (.001); Factor 2: K-ABC .24 (.02), Wechsler .30 (002); Factor 3: K-ABC .21 (.04), Wechsler .22 (.03). Correlations of factor scores on Factor 4 and Factor 5 with the screening measures did not reach the .05 level of significance.

Based on the results of the item and factor analyses, a composite scale was developed from the 20 items in boldface in Table 1. Correlations were then calculated between this scale and scores on each of the five factors. A strong relationship was found with Factor 1 ($r = .92$); relatively low correlations with Factors 2 and 3 ($r = .25$ and $r = .23$ respectively, each significant at the .05 level); and nonsignificant correlations with Factors 4 and 5 ($r = .006$ and $r = .001$, respectively).

Table 1

Correlations of Questionnaire Items[1] with Test Scores and Factors[2]

	Mean[3]	Screening		Unrotated Factors				
		K-ABC	Wechs[4]	1	2	3	4	5
Math-related skills								
Repeat own address	1.83					–.38		
Repeat own phone #	1.97		.19		–.42	–.46		
Others' address/phone	1.62							–.53
Count 20 things	2.00							
Comment # relationships	1.98							
Comment speed-limit sign	1.87	.20						–.69
Read speedometer	1.60	.26	.18					
Board game w/ counting	1.98							
Competitive game no help	1.23	.27	.31	.35				
Add numbers to 10	1.98							
Add numbers to 20	1.77	.20	.23	.49	.36			
Add 2-dig. #s, no carry	1.47	.33	.39	.51	.51			
Add 2-dig. #s, carry	.78	.41	.43	.48				
Figure diff. 9 and 2	1.91	.29	.24					–.41
Figure diff. 21 and 9	1.28	.23	.18	.50				–.36
Count 100 by 10's	1.96							
Count 1000 by 100's	1.56	.36	.31	.58				
Make change quarter	1.32	.39	.43	.36	.44		.47	
Make change $1	1.08	.32	.34		.39	.35	.50	
Measure recipe w/o help	.58	.35	.28	.47				
Nickel, dime worth more	1.83	.30	.25	.45				.38
Know days of week	1.89	.19			.43	–.59		
Know day before Friday	1.89			.38	.44	–.55		
Und. "last/next week"	1.84			.43				
Enjoy math workbooks	1.85	.28	.24		.39			
Which smaller, 6 or 4	2.00							
Which bigger, 33 or 27	1.97	.27	.25	.39				
Comparisons with peers								
Vocabulary	1.52	.23		.63				
Using long sentences	1.45	.33	.29	.62				
Remembering events	1.63			.54	–.36			
Having complex ideas	1.57	.33	.27	.67				
Repeating long story	1.33			.62	–.47			
Solving hard puzzles	1.17							
Drawing	.74						.53	
Reading maps	.79	.32	.22	.53				
Block building	.91						.50	
Listen complex stories	1.54			.44	–.49			
Empathy	1.22	.21		.47			.36	
Reading	1.10	.28	.29	.64				
Writing stories, letters	.87	.18	.23	.66				
Spelling	.81	.22	.20	.67				
Fine motor skills	1.07						.41	

Table 1

Continued

	Mean[3]	Screening		Unrotated Factors				
		K-ABC	Wechs[4]	1	2	3	4	5
Playing music	.44							
Singing	.64	.20	.18			−.56		
Creating stories, games	1.28				−.36			

[1]Bolded items were included in the final scale.
[2]For N=100, a correlation of .20 is significant at the .05 level, .26 at the .01 level, and .33 at the .001 level. Correlations >.17 listed here.
[3]Mean score: Maximum value is 2.0. Higher values indicate that successful performance or comparative advancement was reported by a greater number of parents.
[4]Wechsler score. Arithmetic standard score of WPPSI-R or, if age 6, the higher of WPPSI-R or WISC-III Arithmetic scores.

Discussion

It is clear from these results that parents can, indeed, recognize advanced mathematical ability in their kindergarten-age children. The mean K-ABC score for this group was at the 92nd percentile of the standardization group; the mean of the higher of the two Wechsler scores was at the 95th percentile.

Furthermore, within the questionnaire, more than half of the items were significantly correlated with the two brief screening measures, suggesting that the specific information furnished by parents can be used to screen kindergarten children likely to show advancement in mathematical reasoning. Although for other reasons one might want to include additional items, this study suggests that an instrument composed of only 20 items could be used for such purposes.

Within the parents' descriptions, five factors were represented. The first factor, perhaps most resembling what is usually considered general intelligence, showed the strongest relationship to the 20-item questionnaire (r = .92). This factor was highly heterogeneous and included competence in using mathematical relationships and applying them to everyday life (e.g., in measuring a recipe and making change), a substantial verbal reasoning component, the ability to remember complex information, and the ability to decode other symbolic systems such as maps and written language. The screening measures correlated rather weakly with factors reflecting short- and long-term memory and rote (rehearsed) memory and not at all with the two brief factors characterized by spatial reasoning and specific relational knowledge. Indirectly, this information further validates the screening measures as tests of quantitative reasoning rather than, as some have suggested, simply as tests of rote memorization of number facts.

Interpreting the above information in conjunction with the study by Louis and Lewis (1992) cited initially, we find that higher screening-test scores were indeed correlated with more complex reasoning and memory and less with specific knowledge and rote-memorized information.

Although these parents had nominated their children as being significantly advanced in mathematical reasoning (between "somewhat advanced" and "very advanced"), they did not see them, as a group, as equally advanced in other developmental domains when compared with their age peers. Although the parents reported distinct advancement (mean scores above 1.3) in verbal competence (vocabulary, using long sentences, having complex ideas, and listening to complex stories) and in memory (memory for events, repeating a long story), they reported as "somewhat advanced" levels of competence (mean scores .7 to 1.3) in skills reflecting spatial reasoning (reading maps, block building, drawing, "hard" puzzles), nonmathematical school-related skills (reading, spelling, writing), empathy, and fine motor skills. With the exception of playing music and solving puzzles, almost all these items were represented on one or more of the factors described above, all of which also included some mathematical behaviors. These facts suggest that mathematical skills do not represent an isolated or encapsulated domain but that the skills relate in many ways to other aspects of children's development.

Numerous further directions for research are suggested: Even younger groups of children might be examined. The utility of the questionnaire for kindergarten teachers might be explored. The questionnaire might also be used with parents or teachers in an effort to identify young children in disadvantaged circumstances whose mathematical talents might otherwise be overlooked and/or whose parents might not take the initiative, even after suggestions by teachers, to nominate their own children.

This study presents one way to utilize parent information to discover children whose mathematical reasoning is advanced. All too frequently, the kindergarten curriculum, especially a half-day curriculum, glances lightly over "readiness" exercises and fails to illuminate—or nurture—the maturity of children's curiosity about mathematics and their ability to reason mathematically about their world. Multiple sources of information are useful in finding these children so that we may encourage their curiosity and meet their growing needs for challenge.

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