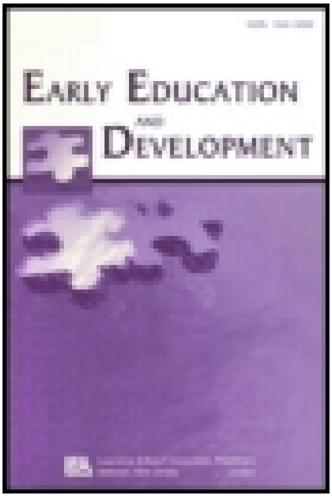

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A Time Lag Analysis of Temporal Relations Between Motivation, Academic Achievement, and Two Cognitive Abilities

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Research Findings: The present study employed a time lag design to assess temporal relationships between motivation, academic achievement, and cognitive development. Eighty-one children from 2 preschool programs were measured twice, with an 11-week time lag, on 2 measures of motivation (marble drop task, bean bag toss task), 2 measures of cognitive development (seriation task, oddity principle task), and 2 measures of academic achievement from the Woodcock–Johnson III (Letter–Word Identification Scale, Applied Problems Scale). There were significant correlations between all of these variables. One clear-cut temporal relationship was found: Prior motivation predicted later academic achievement, but not vice versa. There was also some evidence of temporal relations between motivation and cognitive development, and between cognitive development and academic achievement, but the evidence for these relations was not as conclusive. *Practice or Policy:* It appears that at the preschool level, maintaining children's motivation is paramount. Curricula should be shaped with that primary goal as a high priority, as it appears that it will be followed by academic progress.

Relationships between motivation and academic achievement (Smiley & Dweck, 1994; Sorenson & Maehr, 1977; Veroff, 1969) and between cognitive development and academic achievement (Campbell, Pungello, Miller-Johnson, Burchinal, & Ramey, 2001; Schweinhart & Weikart, 1988; Schweinhart, Weikart, & Larner, 1986) have been well documented. It may be useful to examine how motivation,

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academic achievement, and cognitive development are interrelated. Is there a temporal direction to the relationship? If there is a temporal relationship, in which direction is it? More success with schoolwork could inspire sustained motivation to invest in schoolwork, but of course higher motivation could produce better academic work. Investment in schoolwork could stimulate cognitive development, but who would doubt that better cognitive development might lead to better schoolwork? Relations might be reciprocal or bidirectional. Researchers have been hindered in drawing conclusions as to the direction of the relationships between these factors because these factors cannot be directly manipulated. The major alternatives are either time lag (cross-lagged) studies, structural equation modeling, or path analysis studies. The present study utilized a time lag design to identify the direction of temporal relationships between direct measures of preschool children's long-term motivation, academic achievement, and cognitive development.

> Why do some students approach school tasks eagerly and work diligently on school assignments, while others avoid schoolwork or work half-heartedly? Why do some children enjoy learning in and out of school and take pride in their accomplishments, while others rarely seek opportunities to learn on their own and are anxious and unhappy in school? (Stipek, 1988, p. xi)

The answers to such questions have been more elusive than one might think.

For educators, researchers, and parents, it is easy to recognize high motivation. If a child is engrossed in an activity and remains oblivious to all else, motivation is said to be high (Graham & Weiner, 1996). The child's motivation is shown by intensity and persistence (Graham & Weiner, 1996; Karnes & Johnson, 1990). According to Pintrich and Schunk (1996), *motivation* can be defined as a state in which children's goal-directed activity is both instigated and sustained. Children who frequently experience this state with many tasks are high in mastery motivation (Carlton & Winsler, 1998).

Turner and Johnson (2003) contended that mastery motivation influences the development of preacademic and academic skills, and they tested this hypothesis with a sample of "at-risk" African American preschool children. The relationship between mastery motivation and achievement was statistically significant but not robust ($r = .22$, $p < .05$). Other professionals have also contended that differences in mastery motivation influence success in school environments (Barrett & Morgan, 1995; Dweck, 1986; Skinner & Belmont, 1993). However, this intuitively appealing contention is not as well supported by empirical evidence as one might hope.

The preschool years may be particularly important for developing the kind of motivation that underpins performance in elementary school and beyond. Carlton and Winsler (1998) asserted that the "early childhood years are crucial for establishing robust intrinsic motivational orientations which will last a lifetime" (p. 159). They argued that by the time many children reach school age, their intrinsic motivation to solve problems and to learn has declined or been replaced by extrinsically motivated learning. Such a decline in intrinsic motivation would have direct implications for a subsequent decline in achievement. However, empirical evidence for such declines is hard to find.

How, specifically, would intrinsic motivation foster academic achievement? Some research has indicated that intrinsically motivated children use strategies to promote both deeper understanding (cognitive skills) and future applications of their learning (Carlton & Winsler, 1998; Turner & Johnson, 2003). Deci, Vallerand, Pelletier, and Ryan (1991) conceptualized intrinsic motivation as consisting of psychological needs for competence, relatedness, and autonomy or self-determination. Through understanding and believing in their own abilities (competence), children are able to relate to others and establish secure and stable relationships, thus promoting autonomy. At the age of 3, this autonomy manifests itself as a level of self-regulation (Carlton & Winsler, 1998).

Young children develop feelings of competence as they develop more control of their environment. As they mature, preschoolers strengthen their intrinsic motivation through satisfaction of these three basic psychological needs. Carlton and Winsler (1998) further contended that private speech is an indicator that the child is involved in a motivating activity. They suggested that children learn to work their way through problems using verbal skills and the internalization of speech. Preschool children, when challenged by an activity, can scaffold their own behavior through private speech, thus motivating themselves (Berk & Winsler, 1995).

Does motivation actually affect school achievement? The answer seems obvious, but researchers have not provided a clear-cut affirmative. For example, Patrick, Mantzicopoulos, Samarapungavan, and French (2008) studied kindergartners' motivation and achievement in science. Two different achievement tests showed no differences in academic achievement related to motivation, contrary to what might have been expected.

In contrast, Aunola, Leskinen, and Nurmi's (2006) longitudinal study of Finnish children showed a relationship between task motivation and mathematical achievement during preschool and again in first and second grades. Motivation and performance were found to compose a positive feedback circle such that one affected the other continuously as the child developed mathematical skills, although correlations were small.

Does motivation affect the development of cognitive competence? Again, empirical research is sparse and somewhat contradictory. Klaus and Gray's (1968) early study of low-income preschoolers who were followed for 5 years did not find any differences in motivation (measured in a variety of ways) that were associated with either achievement or cognitive competence. They interpreted the lack of significant differences as primarily due to difficulties in measuring young children's mastery motivation, and such measurement *is* difficult. But more recently, Lange, MacKinnon, and Nida (1989) found that teacher ratings of the mastery motivation of 3- and 4-year-olds predicted the children's performance in a recall task. The mastery-oriented children made more effort and were more involved in the memory tasks.

In a comprehensive study of the cognitive development and motivation of preschool and kindergarten children, Stipek and Ryan (1997) assessed children in the fall and spring, then followed up by testing a subsample of children the following spring. Economically disadvantaged children scored lower than advantaged children on each of eight cognitive tests. Stipek and Ryan also found differences on measures of motivation, self-confidence, attitudes toward school, expectations for success, dependency, and preference for challenge. However, unlike the cognitive measures, these did not necessarily favor the advantaged children. Hence, higher motivation is not necessarily associated with higher cognitive competence.

For example, disadvantaged children generally entered with and maintained higher scores on perceptions of competence and attitudes toward school, whereas advantaged children's anxiety increased during the year. Advantaged children also tended to make more negative social comparisons, seek more help, and look bored more often than disadvantaged children. However, in a later study (Stipek, Feiler, Daniels, & Milburn, 1995), disadvantaged kindergartners, who again had poorer cognitive skills, became more negative over time in their views of their own competencies and their attitudes toward school. The contradictions between the studies have not been resolved.

All three variables—motivation, cognitive competence, and achievement—were measured simultaneously by Spinath, Spinath, Harlaar, and Plomin (2006) to see whether cognitive ability or motivation was a better predictor of school achievement for nearly 1,700 nine-year-olds in the United Kingdom. Self-perception (a form of motivation) was measured by having the children rate how good they thought they were at three different activities (mathematics, English, and science), and intrinsic motivation was measured by having them rate how much they liked each of the activities. In mathematics and English, the two types of motivation were stronger predictors of achievement than psychometric intelligence, and self-perception was a stronger predictor than intrinsic motivation. This study is especially valuable because of its assessment of all three variables for the same large sample. However, self-ratings of motivation in the context of these three subject matters may have been contaminated by the children's knowledge of how well they were doing in those subject matters.

MEASURING PRESCHOOLERS' COGNITIVE ABILITY

It is difficult to measure cognitive development in young children separately from what they have learned or been taught, since scores on traditional IQ tests are heavily influenced by the latter. One approach is to use measures of cognitive development developed by Piaget, since they are relatively universal and seldom directly taught to children by adults. Silliphant (1983) found that kindergartners' scores on measures of classification, seriation, and conservation at the outset of kindergarten predicted their academic achievement for Grades K through 3. In a meta-analysis of children whose mental ages ranged from 4 to 6 years, Pasnak, Willson-Quayle, and Whitten (1998) found correlations ranging from .66 to .85 between classification by oddity, seriation, the Slosson Intelligence Test, the Peabody Picture Vocabulary Test, and the Peabody Individual Achievement Test. Ciancio, Rojas, McMahon, and Pasnak (2001) and Pasnak, Savage, Ferguson, and Levit (2006) also found that understanding of the oddity principle and seriation correlated with verbal and quantitative achievement among preschoolers. These early forms of abstract thought develop naturally and are not contaminated by academic achievement. They are easy to measure and require very little verbal communication. Hence, these measures of cognitive development, which lack the social onus that IQ tests have with parents and school personnel, were chosen for the present research.

MEASURING PRESCHOOLERS' MOTIVATION

Measures of motivation in preschoolers that involve parent or teacher reports are useful, but they can be affected by lack of skill or interest on the part of the observer, bias, or, in the case of parents, unfamiliarity with the full range of other children's behavior. They are above all subjective estimates rather than objective measurements. Still other measures such as the Gumpgookies (Bridgeman & Shipman, 1978), which was specifically designed for use with preschool children, produce response set–type answers in young children. Others assess children via verbal discussions. Bardouille-Crema, Black, and Feldhusen (1986), for example, used a combination of verbal techniques and manipulatives to assess children in Grades 1 through 6 on five Piagetian tasks. However, such discussions may not produce accurate assessments with preschoolers, who are not always able to verbalize their thoughts and feelings accurately.

Our intent was to use direct measures of motivation that would engage preschoolers without making them suspicious or involving them in verbal conversations that could produce inaccurate assessments or make them feel uncomfortable. The marble drop task (Zigler, 1961)—dropping marbles into holes in a box—is fun for young children when there are *no* rewards or external forms of encouragement, and it requires almost nothing in terms of preexisting knowledge or ability. It provides a measure of how intrinsically motivated children are to engage in a playful activity that is natural and produces some sense of accomplishment. The bag toss game also provides a measure of intrinsic motivation (Ward, 1969). Fabes

(1986) and Sorenson and Maehr (1977) found that, if given a choice, highly motivated young children usually chose a "moderately difficult" medium distance from which to toss a bean bag rather than a very close (easy) or a very far (very difficult) distance. Hence, the marble drop and bag toss games were used as nonverbal measures of intrinsic motivation.

THE RESEARCH PROBLEM

Assessing the temporal relations between the three variables of motivation, cognitive development, and academic achievement is difficult because these variables are not manipulable and because relations may be reciprocal or bidirectional. A first step to solving these problems whenever correlated variables cannot be manipulated is to employ a time lag design to identify the temporal direction of any relations that may exist. With time lag analysis, children's scores on two or more variables are measured twice: once at an early or baseline time (Time 1) and then again after an interval sufficient for one to have an effect on the other (Time 2). Evans (1985) noted that when determining directionality in relationships, scientists assume that causes work forward in time. Time precedence is a necessary, although insufficient, condition for establishing causality. The "cause" *must* precede its "effect" by some amount of time; the effect cannot precede the cause, and they cannot be simultaneous. Time lag analyses cannot prove causality (Cook & Campbell, 1979; Rogosa, 1980), but they can show whether prior changes in one variable are or are not associated with later changes in another. Such a time relationship would be a necessary condition for a causal relation to exist and would identify which possibilities might most profitably be pursued in further research designed to demonstrate causality. Hence, in the present research a time lag design was used in an attempt to identify any such temporal relationships that exist between motivation, cognitive development, and academic achievement in preschool children.

HYPOTHESES

Three hypotheses were tested. The first hypothesis was that there is a temporal relationship between motivation and cognitive development. If the correlation is different for Time 1 motivation to Time 2 cognitive development than for Time 1 cognitive development to Time 2 motivation, earlier changes in one variable are associated with later changes in the other, but not vice versa. This would indicate the temporal direction of any relationship that exists.

The second hypothesis was that there is a temporal relationship between motivation and academic achievement in preschool children. The time contingencies were the same as in the first hypothesis, but the variables were motivation and academic achievement. The third hypothesis was parallel to the first two, except that the variables were cognitive development and academic achievement.

In all cases, the absence of a significantly stronger cross-correlation across time in one direction than the other is a negative finding. It is usually interpreted as evidence against there being a temporal relation between the variables.

METHOD

Participants

Sample. Tests were administered to 19 children from the George Mason University (GMU) Child Development Center (a preschool for children of GMU faculty, staff, and students) and to 68 children from the Loudoun County Striving Towards Excellence in Preschool (STEP) Program (a preschool for which admission is based on low income, having English as a second language, and/or a performance issue). More precise socioeconomic data were not available because of privacy policies. There were 38 boys and 49 girls ranging in age from 4 to 5 years old; 56% were Latino, 26% were Caucasian, 8% were African American, 6% were Native American, and 3% were Asian.

Power analysis. A power analysis determined that for r, 85 participants would be needed to avoid a Type II error (Keppel, 1991) assuming a medium effect size (r = .30–.50) and a .80 estimated power at the .05 level (two-tailed). Medium effect sizes are, according to Cohen (1992), typical of those reported in behavioral research. Such effects would indicate that from 10% to 25% of the differences between children on one variable could be accounted for by a linear relation to the other. Given the myriad factors that affect the three variables under study, such relations would be quite meaningful.

Procedures

All children were pretested (Time 1) on academic achievement, cognitive development, and motivation in six individual sessions in a counterbalanced order. Sessions lasted no more than 10 min, except that the marble drop task offered an unlimited amount of time. After 11 weeks, the children were retested (Time 2) in the same manner. This time lag was designed to reduce practice and retention effects and allow sufficient time for temporal relations to appear.

Measures

Marble drop. Children individually watched an adult drop five marbles haphazardly into a wooden 18 × 12 × 8-in box with six holes on top. They were then given 500 marbles and allowed to play as long as they wanted. Children who dropped all 500 marbles into the box were allowed to play again, as often as they wished. The total time each child played and the number of marbles dropped were recorded.

Bag toss. Bean bags and a picture of a clown with a hole cut out in it was mounted on an easel in a modification of Fabes's (1986) method. Ten lines were drawn 1 ft apart in front of the easel, with Line 1 only 1 ft from the easel. An adult threw a bag through the hole and then gave each child a practice trial behind Line 5. Children threw 10 bags while standing behind their choice of the 10 lines. The number of hits, the average line the child chose to stand behind, and the number of times the child moved closer to or further from the target were recorded.

Seriation test. For each of 10 problems, each child was presented with a set of ordinary objects and asked to line them up from smallest to largest. Two problems had three objects, two had four objects, and for two problems the child was to seriate three objects and then was given a fourth to insert into the series. There were also two problems that required inserting a fifth object into a series of four, and two requiring the insertion of a sixth object into a series of five. To encourage participation and to convey the idea of the task, each child was given a small stuffed animal and shown how this animal could put three objects in order for two practice problems. The researcher also used a toy animal to engage children in this play and to show what was desired.

Oddity test. Twelve oddity problems were composed from everyday objects to test each child's understanding of the oddity principle. Each problem had three objects that were alike and one that was different in either form (four problems), size (four problems), or orientation (four problems). Children were asked "Which one is different? Not the same as the rest?" for the oddity by form and oddity by size problems. For the oddity by orientation problems, four identical objects were placed in front of the child, with one object pointing a different way, and the child was asked "Which one is pointing a different way? Not the same way as the others?" The researcher and child used toy animals for the oddity tasks just as in the seriation tasks.

Woodcock–Johnson III. Two subscales, the Letter–Word Identification Scale (Test 1) and the Applied Problems Scale (Test 10), were selected because of their developmental appropriateness for preschoolers. The Letter–Word Identification Scale (Reading Cluster) is a 24-item test that measures an aspect of reading decoding and requires individuals to identify and pronounce isolated letters and words. The Applied Problems Scale (Mathematics Cluster) is a 29-item test of early numeracy that measures an individual's ability to analyze and solve practical mathematical problems. The Woodcock–Johnson III has been used successfully with preschoolers in several studies, including that of Stipek et al. (1995). The manual gives reliability coefficients of .79 at age 4 and .86 at age 5. The language used in these scales was simple enough for all of the children to be able to answer the questions late in the preschool year.

RESULTS

Overall Analysis

For the bag toss task, the average line the child chose to stand behind was converted to absolute standard score values since standing extremely close or far away indicates low motivation. Descriptive statistics for the individual preschool programs are presented in Table 1. Table 1 also shows that they differed significantly on nearly all variables, which was fortunate, as the full range of scores these disparate samples provided was essential to the detection of differences in cross-correlations. Tables 2 and 3 depict the correlation coefficients and

TABLE 1
Statistics for the GMU Child Development Center and STEP

	GMU		*STEP*			
Variable	*M*	*SD*	*M*	*SD*	*t*	*p*
Marble Duration (T1)	2,042.67	365.64	520.41	430.99	13.63	<.01
Marble Duration (T2)	2,731.11	600.19	714.19	594.05	12.68	<.01
Marbles Dropped (T1)	870.61	104.65	202.05	222.01	12.35	<.01
Marbles Dropped (T2)	581.72	234.22	289.54	284.02	3.99	<.01
Bag Hits (T1)	3.56	1.98	3.32	2.30	0.40	.69
Bag Hits (T2)	3.44	1.79	4.21	2.11	1.41	.16
Bag Line Choice (T1)	3.17	1.74	3.33	1.76	0.34	.73
Bag Line Choice (T2)	3.42	1.76	2.45	1.13	2.81	<.01
Moves to New Line (T1)	0.94	4.35	–1.32	3.35	2.36	<.02
Moves to New Line (T2)	–0.78	2.94	–1.08	2.03	0.50	.62
Seriation (T1)	7.39	2.91	4.73	2.95	3.39	<.01
Seriation (T2)	9.33	1.68	6.08	3.24	4.09	<.01
Oddity (T1)	8.89	2.63	8.08	2.80	1.10	.28
Oddity (T2)	10.94	1.77	9.10	2.36	3.07	<.01
Literacy (T1)	12.78	3.47	8.32	4.66	3.77	<.01
Literacy (T2)	14.06	3.32	10.86	4.09	3.04	<.01
Numeracy (T1)	14.56	4.74	10.16	4.84	3.42	<.01
Numeracy (T2)	17.44	4.25	11.63	4.18	5.19	<.01

Note. GMU = George Mason University; STEP = Striving Towards Excellence in Preschool; T1 = Time 1; T2 = Time 2.

TABLE 2
Time 1 to Time 1 Motivation, Cognitive Development, and Academic Achievement Correlations and *p* Values

	Motivation					Cognitive Development		Academic Achievement	
Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Motivation									
1. Marble Drop	—	.913*	.025	–.050	.217	.331*	.092	.304*	.241*
Duration		.000	.826	.660	.052	.003	.415	.006	.030
2. Marbles		—	–.051	.067	.274*	.304*	.077	.258*	.222*
Dropped			.653	.555	.013	.006	.494	.020	.046
3. Bag Hits			—	–.693*	–.183	–.068	–.030	–.038	.065
				.000	.103	.548	.790	.736	.566
4. Bag Line				—	.229*	–.091	–.082	–.148	–.204
Choice					.040	.418	.465	.187	.068
5. Moves to					—	.074	–.008	.058	.088
New Line						.511	.940	.604	.435
Cognitive Development									
6. Seriation						—	.594*	.581*	.666*
							.000	.000	.000
7. Oddity							—	.392*	.603
								.000	.000
Academic Achievement									
8. Literacy								—	.605*
									.000
9. Numeracy									—

$^*p < .05$, two-tailed.

p values for simultaneous correlations between variables at Time 1 and at Time 2, respectively. Table 4 shows test–retest relationships for all variables and cross-lagged correlations that tested temporal relations between variables. All correlation coefficients were based on the scores of the 81 participants who had complete data.

Motivation and Cognitive Development

For both marble drop motivation tasks and cognitive development as measured by the oddity principle, Figure 1 shows that there were significant correlations between earlier (Time 1) motivation and later (Time 2) cognitive development but no significant correlations the other way (from Time 1 cognitive development to Time 2 motivation). This suggests—but only suggests—that prior motivation may

TABLE 3
Time 2 to Time 2 Motivation, Cognitive Development, and Academic Achievement Correlation Coefficients and *p* Values

	Motivation					*Cognitive Development*		*Academic Achievement*	
Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Motivation									
1. Marble Drop	—	.715*	–.144	.281*	.053	.358*	.328*	.189	.469*
Duration		.000	.199	.011	.639	.001	.003	.092	.000
2. Marbles		—	–.064	.169	.038	.163	.158	.025	.228*
Dropped			.572	.131	.736	.146	.158	.822	.041
3. Bag Hits			—	–.555*	.022	.007	–.112	.011	–.132
				.000	.847	.953	.320	.924	.240
4. Bag Line				—	.187	.058	.158	.137	.218*
Choice					.094	.607	.158	.223	.051
5. Moves to					—	.162	.225*	.092	.136
New Line						.148	.043	.412	.225
Cognitive Development									
6. Seriation						—	.563*	.441*	.641*
							.000	.000	.000
7. Oddity							—	.363*	.711*
								.001	.000
Academic Achievement									
8. Literacy								—	.519*
									.000
9. Numeracy									—

*$p < .05$, two-tailed.

have some effect on this aspect of subsequent cognitive development. There was no evidence that prior cognitive development affects later motivation.

However, the picture was different for the seriation measure of cognitive development. The motivation and seriation cross-correlations were significant in both directions (see Figure 2), and Fisher z comparisons did not indicate that differences between the cross-correlation coefficients were significant (see Table 5). Hence, there was no evidence for directionality of the correlation between motivation and this measure of cognitive development within the parameters of this study. Taken together, the findings for the cognitive development and motivation variables support the idea that high levels of motivation may be advantageous for preschool children's cognitive development, but that the effect is not general. There was no evidence that the aspects of cognitive development investigated here have an impact on motivation.

TABLE 4
Time 1 to Time 2 Motivation, Cognitive Development, and Academic Achievement Correlation Coefficients and *p* Values

	Motivation, Time 1					*Cognitive Development, Time 1*		*Academic Achievement, Time 1*	
Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Motivation, Time 2									
1. Marble Drop Duration	.783*	.775*	.068	–.034	.173	.355*	.147	.246*	.322*
	.000	.000	.548	.764	.122	.001	.189	.027	.003
2. Marbles Dropped	.499*	.583*	.025	.022	.111	.215*	.104	.031	.060
	.000	.000	.823	.842	.322	.054	.358	.784	.596
3. Bag Hits	–.138	–.198	.227*	–.210	–.359*	–.113	–.002	.028	–.131
	.221	.076	.042	.060	.001	.317	.988	.804	.245
4. Bag Line Choice	.290*	.388*	–.158	.209	.210	.111	.004	.032	.114
	.009	.000	.159	.061	.060	.323	.970	.779	.310
5. Moves to New Line	.062	.029	.121	–.150	.011	.138	.171	.063	.171
	.583	.800	.281	.181	.923	.220	.126	.575	.128
Cognitive Development, Time 2									
6. Seriation	.367*	.325*	.066	–.123	.070	.772*	.465*	.496*	.624*
	.001	.003	.561	.273	.536	.000	.000	.000	.000
7. Oddity	.258*	.220*	.073	–.119	–.054	.621*	.744*	.410*	.635*
	.020	.048	.515	.289	.632	.000	.000	.000	.000
Academic Achievement, Time 2									
8. Literacy	.271*	.234*	–.025	–.136	–.004	.480*	.325*	.865*	.541*
	.014	.035	.828	.225	.974	.000	.003	.000	.000
9. Numeracy	.383*	.408*	.011	–.080	.080	.641*	.643*	.561*	.772*
	.000	.000	.924	.479	.480	.000	.000	.000	.000

*$p < .05$, two-tailed.

Motivation and Academic Achievement

The cross-correlation of .408 for the number of marbles dropped at Time 1 and Applied Problems (numeracy) scores at Time 2 was significantly higher ($z = 2.39$, $p = .023$) than the cross-correlation of .06 between these measures of academic achievement at Time 1 and motivation at Time 2 (see Figure 3). This was evidence that higher levels of motivation were followed by more gains in this aspect of achievement, and lower levels of motivation by lesser gains. There was no hint of any reciprocal or third variable effect, which should have produced roughly equal

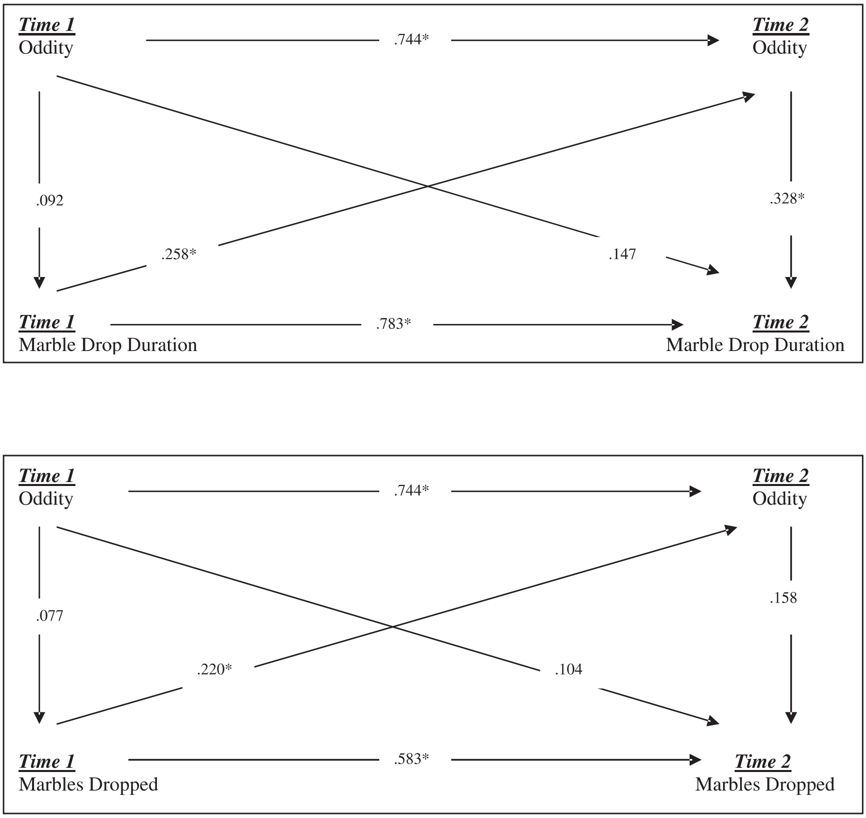


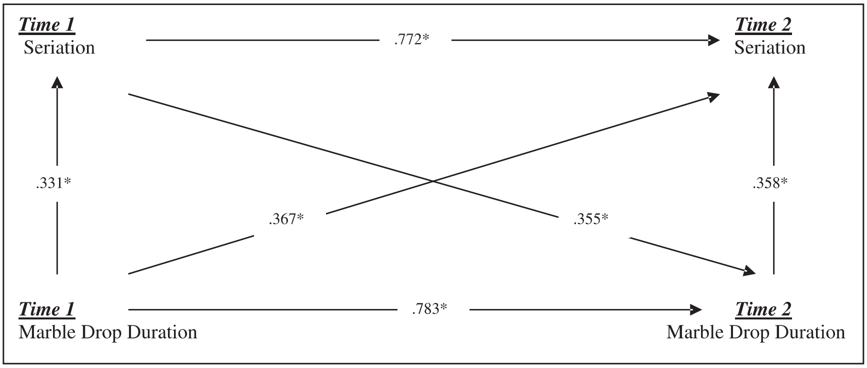
FIGURE 1 The relationship between motivation (marble drop measures) and cognitive development (oddity) measured at Time 1 and Time 2. *$p < .05$, two-tailed.

cross-correlations. Early numeracy did *not* predict later motivation. These findings are the most conclusive evidence for the direction of a temporal relationship that emerged in this study.

There was no hint of any such effect for the verbal achievement measure; the cross-correlations were quite equivalent (see Figure 4).

Cognitive Development and Academic Achievement

The cross-correlation coefficients ranged from .410 to .635 for the various measures of academic achievement at Time 1 and cognitive development at Time 2 and from .325 to .643 for cognitive development at Time 1 and academic achievement at Time 2 (see Figures 5 and 6). These correlations suggest a moderate rela-



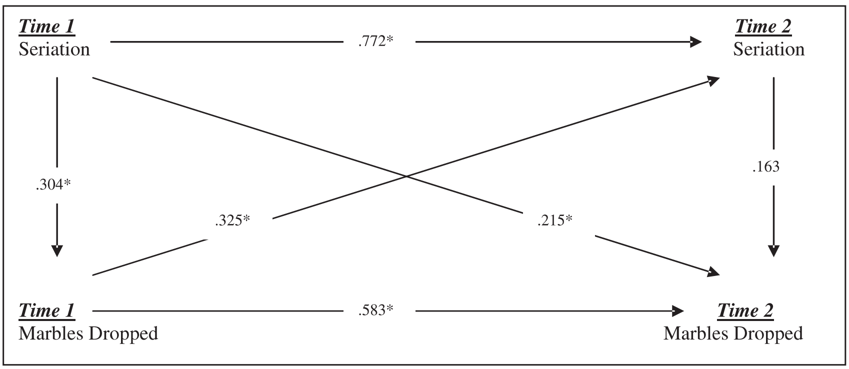


FIGURE 2 The relationship between motivation (marble drop measures) and cognitive development (seriation) measured at Time 1 and Time 2. *$p < .05$, two-tailed.

TABLE 5
Fisher's z Transformations for the Overall Sample ($N = 81$)

Cross-Correlation Variables	*r*	*z*	*p*
Motivation and Cognitive Development			
Duration of Marble Dropping (T1) to Seriation (T2)	.367*	0.076	.398
Seriation (T1) to Duration of Marble Dropping (T2)	.355*		
Duration of Marble Dropping (T1) to Oddity (T2)	.258*	0.764	.299
Oddity (T1) to Duration of Marble Dropping (T2)	.147		
Marbles Dropped (T1) to Seriation (T2)	.325*	0.758	.299
Seriation (T1) to Marbles Dropped (T2)	.215*		
Marbles Dropped (T1) to Oddity (T2)	.220*	0.758	.299
Oddity (T1) to Marbles Dropped (T2)	.104		

(continued)

TABLE 5 (*Continued*)

Cross-Correlation Variables	*r*	*z*	*p*
Bag Hits (T1) to Seriation (T2)	.066	0.318	.380
Seriation (T1) to Bag Hits (T2)	–.113		
Bag Hits (T1) to Oddity (T2)	.073	0.287	.383
Oddity (T1) to Bag Hits (T2)	–.030		
Bag Line Choice (T1) to Seriation (T2)	–.123	0.102	.397
Seriation (T1) to Bag Line Choice (T2)	.111		
Bag Line Choice (T1) to Oddity (T2)	–.119	0.261	.386
Oddity (T1) to Bag Line Choice (T2)	–.082		
Moves to New Line (T1) to Seriation (T2)	.070	0.420	.365
Seriation (T1) to Moves to New Line (T2)	.138		
Moves to New Line (T1)1 to Oddity (T2)	–.054	0.287	.383
Oddity (T1) to Moves to New Line (T2)	.008		
Motivation and Academic Achievement			
Duration of Marble Dropping (T1) to Literacy (T2)	.271*	0.172	.393
Literacy (T1) to Duration of Marble Dropping (T2)	.246*		
Duration of Marble Dropping (T1) to Numeracy (T2)	.383*	0.471	.357
Numeracy (T1) to Duration of Marble Dropping (T2)	.322*		
Marbles Dropped (T1) to Literacy (T2)	.234*	1.33	.165
Literacy (T1) to Marbles Dropped (T2)	.031		
Marbles Dropped (T1) to Numeracy (T2)	.408*	*2.39	.023
Numeracy (T1) to Marbles Dropped (T2)	.060		
Bag Hits (T1) to Literacy (T2)	–.025	0.032	.379
Literacy (T1) to Bag Hits (T2)	.028		
Bag Hits (T1) to Numeracy (T2)	.011	0.771	.297
Numeracy (T1) to Bag Hits (T2)	–.131		
Bag Line Choice (T1) to Literacy (T2)	–.136	0.675	.318
Literacy (T1) to Bag Line Choice (T2)	.032		
Bag Line Choice (T1) to Numeracy (T2)	–.080	0.229	.389
Numeracy (T1) to Bag Line Choice (T2)	.114		
Moves to New Line (T1) to Literacy (T2)	–.004	0.382	.371
Literacy (T1) to Moves to New Line (T2)	.063		
Moves to New Line (T1) to Numeracy (T2)	.080	0.586	.337
Numeracy (T1) to Moves to New Line (T2)	.171		
Cognitive Development and Academic Achievement			
Seriation (T1) to Literacy (T2)	.480*	0.127	.396
Literacy (T1) to Seriation (T2)	.496*		
Seriation (T1) to Numeracy (T2)	.641*	0.159	.394
Numeracy (T1) to Seriation (T2)	.624*		
Oddity (T1) to Literacy (T2)	.325*	0.631	.327
Literacy (T1) to Oddity (T2)	.410*		
Oddity (T1) to Numeracy (T2)	.643*	0.108	.397
Numeracy (T1) to Oddity (T2)	.635*		

Note. T1 = Time 1; T2 = Time 2.
*$p < .05$, two-tailed.

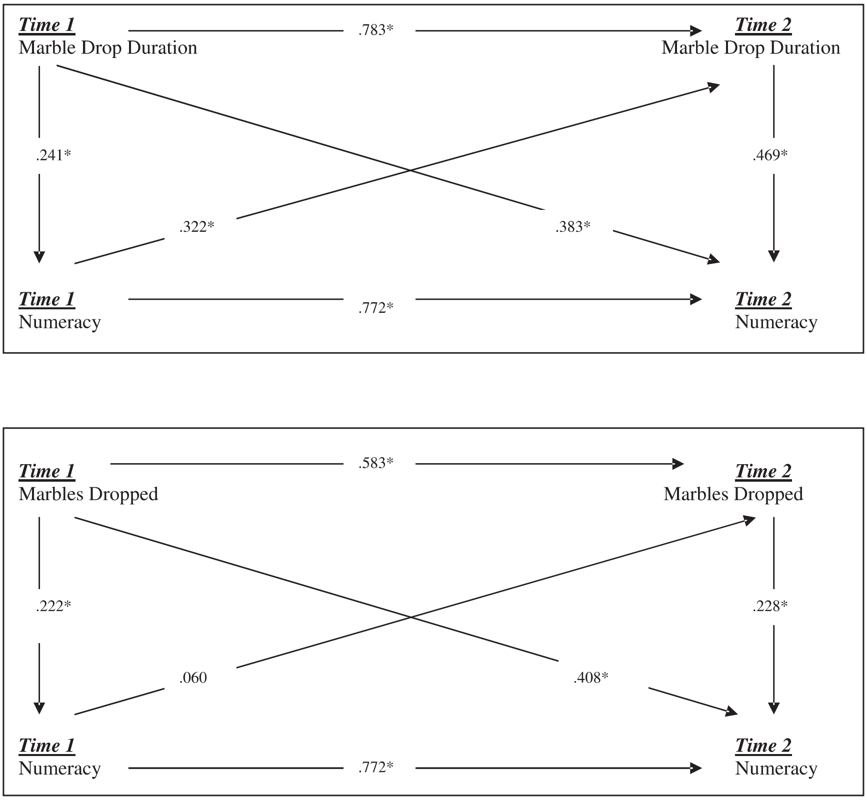


FIGURE 3 The relationship between motivation measures and academic achievement (numeracy) measured at Time 1 and Time 2. $^*p < .05$, two-tailed.

tionship between cognitive development at one time and academic achievement at another. However, Fisher *z* calculations did not indicate a significant difference in the cross-correlation coefficients (see Table 5). Thus, within the parameters of this experiment, there was no evidence for temporality in the relationship.

The four simultaneous correlations between the measures of cognitive development and academic achievement ranged from .392 to .666 at Time 1 and from .363 to .711 at Time 2. They were similar to the correlations between early scores on one variable and later scores on another, which again suggests that if there is a temporal relation, these measures do not reveal it.

Cross-correlation coefficients were also calculated for all variables for the GMU Child Development Center (see Table 6) and STEP (see Table 7) separately. Fisher's *z* transformations showed no significant differences between cross-correlations within either of these populations. Only when the full range of scores dis-

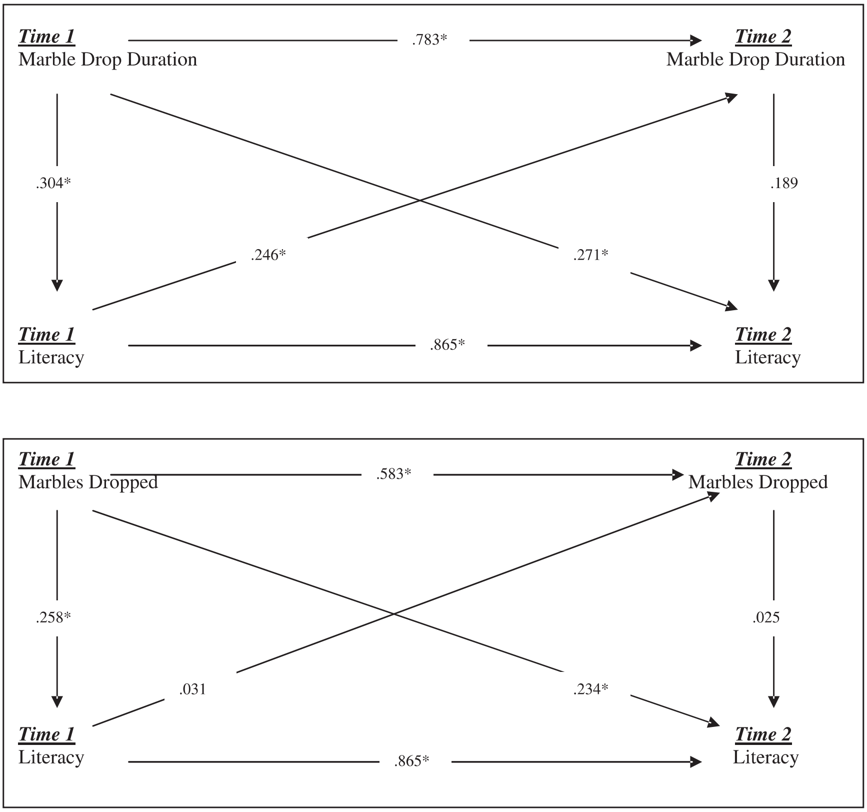


FIGURE 4 The relationship between motivation measures and academic achievement (literacy) measured at Time 1 and Time 2. *$p < .05$, two-tailed.

played by all of the children from both populations was analyzed simultaneously did cross-correlations between variables differ significantly.

Summary of Major Trends

The test–retest correlations from Time 1 to Time 2 ranged from .53 to .86 for all measures except the bag toss. Coefficients of this magnitude indicate a moderate to strong degree of test–retest reliability (Evans, 1985). Bag toss measures did not correlate well with either academic achievement or the cognitive measures. The marble drop motivation measures correlated modestly with understanding of seriation and with both measures of academic achievement at the outset of the research, and with the oddity concept and numeracy (but not the literacy scale) at its conclusion. Most cross-correlations between the marble drop motivation mea-

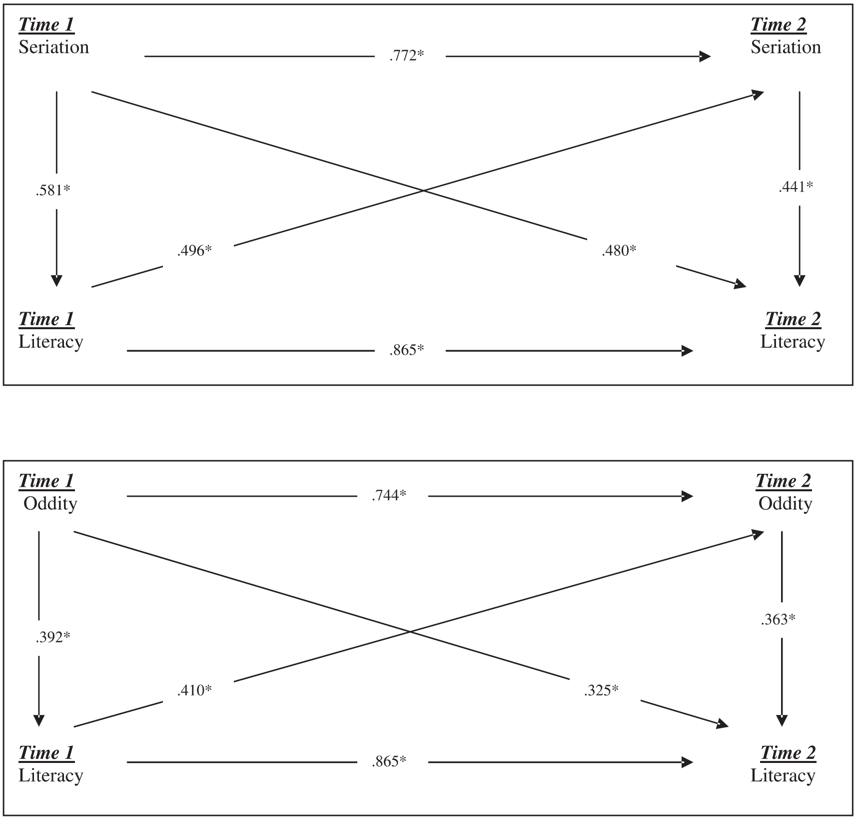


FIGURE 5 The relationship between cognitive development measures and academic achievement (literacy) measured at Time 1 and Time 2. *$p < .05$, two-tailed.

sures, both cognitive measures, and both achievement measures were significant but modest. The only significantly different cross-correlations were those between the one marble drop motivation measure and the numeracy measure. These indicate a temporal effect: Earlier motivation predicts later numeracy, but not vice versa.

DISCUSSION

The 11-week time lag was long enough for developmental changes to occur, as there were increases in all developmental areas examined. In all instances there were stronger positive relationships between motivation at Time 1 and academic achievement at Time 2 than vice versa. This pattern indicates that high or low mo-

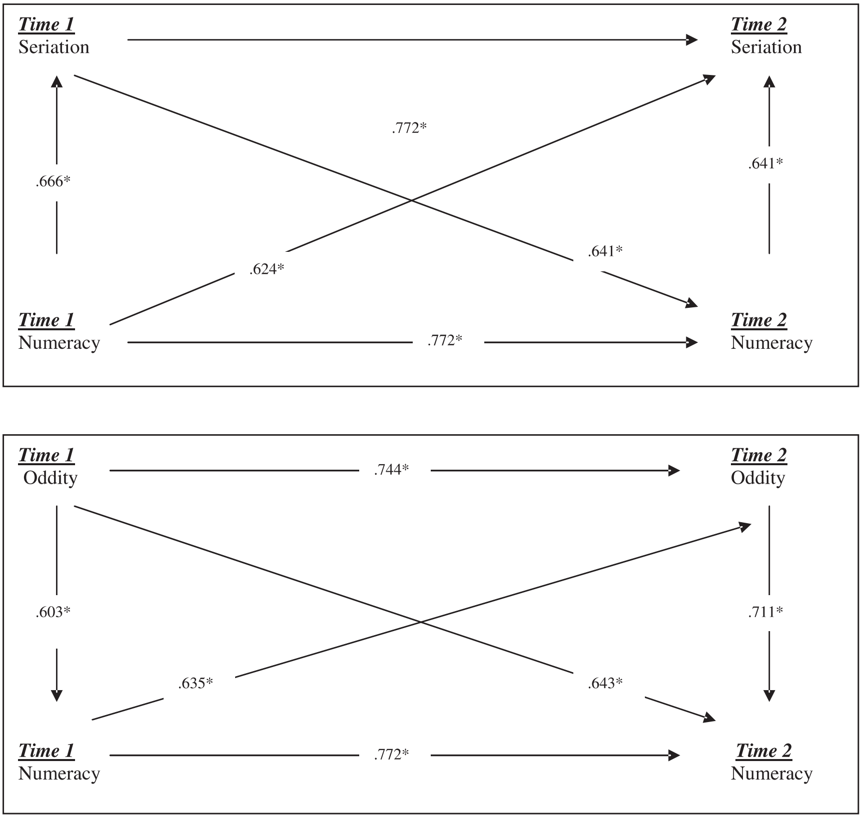


FIGURE 6 The relationship between cognitive development measures and academic achievement (numeracy) measured at Time 1 and Time 2. $*p < .05$, two-tailed.

TABLE 6
Fisher's z Transformations for the George Mason University Child Development Center Sample ($n = 18$)

Cross-Correlation Variables	*r*	*z*	*p*
Motivation and Cognitive Development			
Duration of Marble Dropping (T1) to Seriation (T2)	.193	0.290	.383
Seriation (T1) to Duration of Marble Dropping (T2)	.295		
Duration of Marble Dropping (T1) to Oddity (T2)	.095	0.137	.395
Oddity (T1) to Duration of Marble Dropping (T2)	.044		
Marbles Dropped (T1) to Seriation (T2)	–.162	0.400	.368
Seriation (T1) to Marbles Dropped (T2)	–.015		
Marbles Dropped (T1) to Oddity (T2)	–.110	0.638	.325

(continued)

TABLE 6 (*Continued*)

Cross-Correlation Variables	*r*	*z*	*p*
Oddity (T1) to Marbles Dropped (T2)	–.328		
Bag Hits (T1) to Seriation (T2)	.083	0.140	.395
Seriation (T1) to Bag Hits (T2)	–.137		
Bag Hits (T1) to Oddity (T2)	.111	0.027	.399
Oddity (T1) to Bag Hits (T2)	.099		
Bag Line Choice (T1) to Seriation (T2)	.102	0.260	.386
Seriation (T1) to Bag Line Choice (T2)	.006		
Bag Line Choice (T1) to Oddity (T2)	–.039	0.027	.399
Oddity (T1) to Bag Line Choice (T2)	–.052		
Moves to New Line (T1) to Seriation (T2)	–.102	0.197	.391
Seriation (T1) to Moves to New Line (T2)	–.169		
Moves to New Line (T1) to Oddity (T2)	.038	0.055	.343
Oddity (T1) to Moves to New Line (T2)	.019		
Motivation and Academic Achievement			
Duration of Marble Dropping (T1) to Literacy (T2)	.219	0.573	.339
Literacy (T1) to Duration of Marble Dropping (T2)	–.015		
Duration of Marble Dropping (T1) to Numeracy (T2)	–.070	0.904	.266
Numeracy (T1) to Duration of Marble Dropping (T2)	.379		
Marbles Dropped (T1) to Literacy (T2)	–.091	0.096	.397
Literacy (T1) to Marbles Dropped (T2)	–.053		
Marbles Dropped (T1) to Numeracy (T2)	.013	0.644	.325
Numeracy (T1) to Marbles Dropped (T2)	–.246		
Bag Hits (T1) to Literacy (T2)	.246	1.24	.185
Literacy (T1) to Bag Hits (T2)	.604*		
Bag Hits (T1) to Numeracy (T2)	.179	0.300	.381
Numeracy (T1) to Bag Hits (T2)	–.280		
Bag Line Choice (T1) to Literacy (T2)	–.264	1.33	.165
Literacy (T1) to Bag Line Choice (T2)	–.639*		
Bag Line Choice (T1) to Numeracy (T2)	–.247	0.148	.395
Numeracy (T1) to Bag Line Choice (T2)	.295		
Moves to New Line (T1) to Literacy (T2)	–.241	0.058	.398
Literacy (T1) to Moves to New Line (T2)	.218		
Moves to New Line (T1) to Numeracy (T2)	.116	0.153	.395
Numeracy (T1) to Moves to New Line (T2)	.172		
Cognitive Development and Academic Achievement			
Seriation (T1) to Literacy (T2)	.466	0.364	.374
Literacy (T1) to Seriation (T2)	.356		
Seriation (T1) to Numeracy (T2)	.466	0.696	.312
Numeracy (T1) to Seriation (T2)	.640*		
Oddity (T1) to Literacy (T2)	.385	0.310	.380
Literacy (T1) to Oddity (T2)	.286		
Oddity (T1) to Numeracy (T2)	.631*	0.636	.325
Numeracy (T1) to Oddity (T2)	.749*		

Note. T1 = Time 1; T2 = Time 2.
*$p < .05$, two-tailed.

TABLE 7
Fisher's *z* Transformations for the Striving Towards Excellence in Preschool Sample ($n = 63$)

Cross-Correlation Variables	*r*	*z*	*p*
Motivation and Cognitive Development			
Duration of Marble Dropping (T1) to Seriation (T2)	.014	0.301	.381
Seriation (T1) to Duration of Marble Dropping (T2)	.070		
Duration of Marble Dropping (T1) to Oddity (T2)	–.053	0.219	.389
Oddity (T1) to Duration of Marble Dropping (T2)	.093		
Marbles Dropped (T1) to Seriation (T2)	–.019	0.464	.359
Seriation (T1) to Marbles Dropped (T2)	.103		
Marbles Dropped (T1) to Oddity (T2)	–.080	0.333	.378
Oddity (T1) to Marbles Dropped (T2)	.141		
Bag Hits (T1) to Seriation (T2)	.049	0.027	.399
Seriation (T1) to Bag Hits (T2)	–.045		
Bag Hits (T1) to Oddity (T2)	.054	0.301	.381
Oddity (T1) to Bag Hits (T2)	.000		
Bag Line Choice (T1) to Seriation (T2)	–.153	0.798	.290
Seriation (T1) to Bag Line Choice (T2)	.009		
Bag Line Choice (T1) to Oddity (T2)	–.129	0.552	.343
Oddity (T1) to Bag Line Choice (T2)	–.029		
Moves to New Line (T1) to Seriation (T2)	–.035	1.17	.201
Seriation (T1) to Moves to New Line (T2)	.245		
Moves to New Line (T1) to Oddity (T2)	–.207	0.115	.396
Oddity (T1) to Moves to New Line (T2)	.226		
Motivation and Academic Achievement			
Duration of Marble Dropping (T1) to Literacy (T2)	–.042	0.721	.308
Literacy (T1) to Duration of Marble Dropping (T2)	–.167		
Duration of Marble Dropping (T1) to Numeracy (T2)	–.085	0.273	.385
Numeracy (T1) to Duration of Marble Dropping (T2)	–.035		
Marbles Dropped (T1) to Literacy (T2)	–.048	0.667	.319
Literacy (T1) to Marbles Dropped (T2)	–.171		
Marbles Dropped (T1) to Numeracy (T2)	–.004	0.355	.374
Numeracy (T1) to Marbles Dropped (T2)	–.071		
Bag Hits (T1) to Literacy (T2)	–.096	0.464	.359
Literacy (T1) to Bag Hits (T2)	.010		
Bag Hits (T1) to Numeracy (T2)	–.060	0.137	.395
Numeracy (T1) to Bag Hits (T2)	–.036		
Bag Line Choice (T1) to Literacy (T2)	–.102	0.164	.394
Literacy (T1) to Bag Line Choice (T2)	.068		
Bag Line Choice (T1) to Numeracy (T2)	–.022	0.525	.348
Numeracy (T1) to Bag Line Choice (T2)	–.113		
Moves to New Line (T1) to Literacy (T2)	–.055	0.273	.385
Literacy (T1) to Moves to New Line (T2)	–.004		
Moves to New Line (T1) to Numeracy (T2)	–.124	0.191	.392
Numeracy (T1) to Moves to New Line (T2)	.161		

(continued)

TABLE 7 (*Continued*)

Cross-Correlation Variables	*r*	*z*	*p*
Cognitive Development and Academic Achievement			
Seriation (T1) to Literacy (T2)	.403*	0.00	.399
Literacy (T1) to Seriation (T2)	.405*		
Seriation (T1) to Numeracy (T2)	.601*	0.328	.378
Numeracy (T1) to Seriation (T2)	.561*		
Oddity (T1) to Literacy (T2)	.287*	0.273	.385
Literacy (T1) to Oddity (T2)	.330*		
Oddity (T1) to Numeracy (T2)	.691*	1.21	.192
Numeracy (T1) to Oddity (T2)	.558*		

Note. T1 = Time 1; T2 = Time 2.
*$p < .05$, two-tailed.

tivation is followed by high or low academic achievement. The difference between the cross-correlations was statistically significant for one marble drop task and the numeracy scale. This finding indicates that *if* there is a causal relationship between the aspect of motivation measured by this task and the type of numeracy measured by this scale, it is more likely that increased motivation produces increased achievement than vice versa. The fundamental principle of the time lag method is that the cause must precede its effect. Here, earlier motivation predicted later achievement but not vice versa. The two variables did not predict each other equally, as might be the case if they constituted a feedback circle (e.g., Aunola et al., 2006) or if underlying variables determined both. This is the most suggestive evidence the time lag analysis produced in this study. Some researchers have regarded such relationships as good evidence for causality (Calsyn, 1976; Crano & Mellon, 1978; Duncan, 1969; Humphreys & Stubbs, 1977). However, methodologists (Cook & Campbell, 1979; Rogosa, 1980) have presented effective mathematical arguments that final proof of causality is impossible with time lag methods. In their view, a true experiment in which the intrinsic motivation of children is randomly increased or decreased would be needed. The problem for developmental psychologists and educators is that even if it were ethical, it would be hard to see how randomized manipulations of children's intrinsic motivation could be accomplished.

The other patterns of correlation found in this study are promising in the sense that they provide a good foundation for the further study of the relationship between motivation, cognitive development, and academic achievement. For example, stronger positive correlations were found for the relationship between motivation at Time 1 and cognitive development at Time 2 than for the reverse in all instances. Not all correlations between cognitive development at Time 1 and motivation at Time 2 were significant. Although this pattern is suggestive, it does not justify the inference that changes in motivation precede subsequent changes in the aspects of cognitive development that were measured, because the differences between these correlations were not statistically significant. That issue remains in doubt, but the finding of Lange et al. (1989) that there is a relation between motivation and cognitive development was supported.

The positive cross-correlations between cognitive development and academic achievement were generally respectable and equivalent (see Figures 5 and 6). This makes it difficult to draw any inferences about temporal relationships between cognitive development and academic achievement. Changes that occur in either may predict changes in the other equally well, with the direction of the relationship unpredictable because of reciprocity or bidirectionality.

Strengths and Weaknesses of This Research

Generalization of the results of this study is limited by the population studied, the measures used, and the methodology employed. For example, even though several studies (Pasnak, Hansbarger, Dodson, Hart, & Blaha, 1996; Pasnak et al., 2007; Pasnak, McCutcheon, Holt, & Campbell, 1991; Silliphant, 1983) have shown that mastery of the oddity principle and seriation correlates with children's verbal and quantitative abilities, these are only two aspects of cognitive development.

A significant feature of this research is that two very different preschool programs were examined. This was opportunistic, but measures were collected from all children simultaneously, with careful attention to procedural fidelity. Cross-correlations for the whole group were higher than those for either preschool. This could have been predicted from the descriptive statistics for the two groups. There were exceptions, but children in the GMU program generally made high scores, those in the STEP program low scores, and the differences were significant for most variables. This provided a full range of scores, with sufficient numbers of scores at the high and low ends of the continua measured to avoid artificially restricting the possible size of correlation coefficients (Marascuilo & Serlin, 1988, p. 90). It allowed for the detection of a relation that applies to both samples but that would have been undetectable from one sample alone. It is not that there was no relation between motivation and numeracy for the STEP sample and not that there was no relation between motivation and numeracy for the GMU sample. The proper interpretation of the effect of truncated range is that the relationship exists in both samples but cannot be adequately detected without the full range of scores that is provided when the two samples are combined. Guilford and Fruchter (1978, pp. 325–326) showed this consequence of truncated range very effectively with a reanalysis of data from a World War II study of student pilots. This is important for future researchers to remember when choosing samples. A study of the low-income children from the STEP program alone, or the higher income children from the GMU program alone, would not have been able to detect the temporal relationship found in this study, even though it existed. The size of correlation coefficients depends disproportionately on the pairing of very high or very low *z* scores, which of course depends on having enough subjects who make high scores and enough who make low scores. *This phenomenon may explain some of the negative findings that have clouded the research literature.* When samples have only low-income or only high-income children, the truncated range of scores prevents detection of many linear relations that exist but that cannot manifest themselves adequately over the limited range of values the sample produces.

The time lag design employed here is not without its limitations, even though, as Boker, Xu, Rotondo, and King (2002) noted, the time lag technique has been used in psychological research for some time now and has sometimes been advocated strongly. McArdle and Woodcock (1997) employed time lag models to examine developmental change in children ages 5 through 19 who participated in the Woodcock–Johnson Psycho-Educational Battery–Revised standardization sample. They contended that use of their time lag extension of a test–retest design permitted the structural separation of some potentially important developmental components. It seems likely that developmental psychologists and educators will increasingly turn to time lag designs to determine the temporal direction of relations when participant characteristics cannot be effectively manipulated. The recent study by Aunola et al. (2006) is an example. However, this methodology is not universally well received.

Rogosa (1980) argued that one assumption of the time lag model is that the psychological processes that influence individual subjects are static. If this argument is correct, the problem with this assumption is that changes in these influences during the course of the time between Time 1 and Time 2 reduce the size of cross-correlations. This reduces the likelihood of significant differences in cross-correlations but does not lead to false positives. Another potentially important feature in the present research is that the variance in children's scores on the motivation measures increased between Time 1 and Time 2. Rogosa showed that differences between cross-lagged correlations will increase as variance increases. This is problematic; in most research, differences in the effect of a variable are harder to detect when variance increases.

There are other problems with time lag approaches. Cook and Campbell (1979), Rogosa (1980), and others have generated path analyses that could produce asymmetries in cross-correlations even when there was no temporal relation between variables. More frequent comparisons of cross-lagged correlations (i.e., adding Time 3, Time 4, … Time N) would improve time lag designs. However, even if so improved, it is doubtful whether time lag designs can be entirely conclusive.

An additional feature of this project was that it attempted direct measures of each child's existing motivation instead of using parent or teacher ratings or short-term artificial manipulations. This may be regarded as a strength, in that adult ratings are indirect and subjective. Experimental manipulations may produce short-term changes, but it is the sustained motivation a preschooler brings to many aspects of his or her environment that is likely to affect academic and cognitive development.

Conclusions and Implications

The need for further study of relations between motivation and achievement was stressed by Carlton and Winsler (1998), who posited that patterns of motivation are established at an early age and are crucial for establishing robust intrinsic motivations that will last a lifetime. The need for such study was also stressed by Dweck (1986), who stated that educationally relevant conceptions of motivation have been elusive.

If suitable measures of motivation can be found, it will be difficult for researchers to identify the direction of relations with samples that do not have many children at the upper or lower ends of the motivation spectrum.

Time lag approaches can be useful in trying to identify the temporal relations between correlated variables. However, they have weaknesses. Rather than the temporal relations that this study explored, it is recommended that future research use structural equation models with multiple latent variables to assess causal relations.

To promote increases in children's cognitive development and academic achievement, psychologists and educators should focus on increasing children's intrinsic motivation in educationally relevant ways. Intensive early childhood programs are designed to partially offset the negative effects of poverty on cognitive and academic development (Campbell et al., 2001; Schweinhart & Weikart, 1988; Schweinhart et al., 1986). Their underlying philosophy is that they can improve cognitive development and hence academic development. The present study indicates that a focus on improving preschoolers' motivation might produce subsequent improvements in academic achievement and perhaps in cognitive development, whereas the opposite is probably not true.

ACKNOWLEDGMENT

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