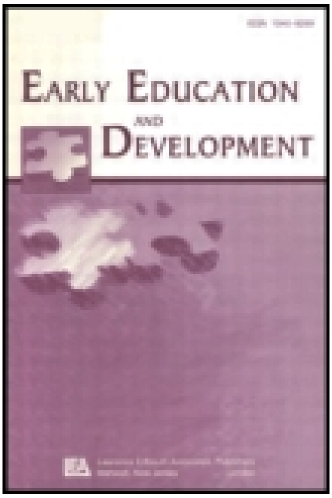

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Benefits of an Intervention Focused on Oddity and Seriation

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Research Findings: A total of 72 Head Start children (*M* age = 53.26 months, *SD* = 5.07) were randomly assigned to 4 conditions. Some were taught the oddity principle (choosing the object that differs from others in a group) and seriation (ordering objects on a dimension and inserting new objects into such orders), which are forms of thinking that develop naturally at about age 4. Others were taught letters or numbers or were engaged in art activities in sessions matched in frequency, timing, and extent. Toy animals were used as props in lessons that scaffolded the children's learning. Preschoolers in the cognitive group improved their cognitive skills significantly more than the others and also became better than the numbers or art groups at identifying letters, as measured by the Letters and Words scale of the Stanford Early School Achievement Test 2. This indicates that with improved oddity and seriation skills, children profited more from lessons and letter sounds offered to all children by their classroom teacher. Comparable results were demonstrated for the oddity and seriation instruction and progress in counting and adding and subtracting objects as measured by the Woodcock–Johnson III Applied Problems scale. *Practice or Policy:* The content and procedures embodied in this research enable children who are economically disadvantaged to make progress in learning letters and in numeracy when enrolled in preschool. Brief periods of such activities for most of the school year may be an effective supplement to lessons on letters, letter sounds, and numeracy offered in preschool curricula.

The purpose of this study was to teach preschoolers the oddity principle (a form of classification) and also unidimensional seriation, which is the ability to order items along a dimension of magnitude. These are abstract principles of thinking that normally develop unaided. Children's mastery of classification and seriation at the outset of kindergarten predicts their achievement on a variety of standardized tests over the next 3 years (Silliphant, 1983), and improving kindergartners' understanding of oddity and unidimensional seriation specifically improves their subsequent academic performance (Kidd, Pasnak, Gadzichowski, Ferral-Like, & Gallington, 2008; Pasnak, Kidd, et al. 2007). Hence, it seemed reasonable to assess the effects of such

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instruction on preschoolers, particularly those who were lagging in developing an understanding of the relations involved in these forms of abstraction.

The ability to understand relations is central to children's cognitive development (Gentner & Christie, 2008). The ability to abstract relationships, and to generalize these abstractions, is a crucial difference between more mature and less mature learners in a variety of domains (Son, Smith, & Goldstone, 2008). Young children are highly variable in the extent to which they have developed their abstractive abilities. There is what has sometimes been termed a *relational shift* (Gentner, 1988; Gentner & Rattermann, 1991) from attending to relations between objects to the specific attributes of the objects. This shift takes place gradually and at different rates for different children from preschool to the end of elementary school (Sternberg & Downing, 1982). Of interest in the current study are two forms of abstraction: oddity and seriation.

One of the earliest abstract relations that children understand is the oddity principle (i.e., what makes one object in a group ''odd'' or different than the rest; McCormick, Campbell, Pasnak, & Perry, 1990; Pasnak, Campbell, Perry, & McCormick, 1989). If a child has three round beads and a fourth square bead, the square bead is odd, but if three beads are square and one round, the round bead is odd. Understanding such relationships is emergent at about age 4 and emerges sooner for some dimensions, such as color, than for others, such as shape or orientation (Gadzichowski & Pasnak, 2009). It has not been studied much by psychologists. The most notable exceptions are training studies by Chalmers and Halford (2003), who used a computerized multiple choice method; Pasnak, Maccubbin, and Ferral-Like (2007), who used concrete objects in a form of structured play; and Soraci et al. (1991), who used an operant apparatus featuring banks of lights in a stimulus choice–reward paradigm.

Researchers have had varying degrees of success in teaching oddity to children. Soraci et al. (1991) had a great deal of difficulty using operant methods to teach oddity to preschoolers, ultimately resorting to a bimodal procedure to enable the children to select the odd array from banks of lights. Chalmers and Halford (2003), in contrast, had little difficulty training preschoolers to select the odd object when the dimensions involved were color, shape, or size. The success of their study may have been due in part to the dimensions of oddity they chose: Color and size are the two dimensions to which children first apply the oddity principle without instruction (Gadzichowski & Pasnak, 2009).

Pasnak, Maccubbin, et al. (2007) used a form of structured play to teach oddity to preschoolers who had not yet developed an understanding of it. Their method improved the children's understanding of the oddity principle, although the children did not completely master it. These children were compared with classmates who had an equal number of sessions on games aimed at improving their identification and recognition of letters. The two groups made similar scores on the Woodcock–Johnson Letter-Word Identification scale, but those who received the oddity instruction made significantly better scores on the Woodcock–Johnson Applied Problems (numeracy) scale, which, it should be noted, does *not* measure oddity directly. Pasnak, Maccubbin, et al. interpreted these results as showing that improved abstraction, in the sense of understanding what made one item different from others, improved numeracy. Presumably the children with improved oddity were better able to profit from numeracy activities the preschool teachers offered their whole class as part of the preschool curriculum. Likewise, being able to abstract relevant differences probably helped the preschoolers in letter identification and recognition as much as the control lessons aimed more directly at those abilities. The preschool curricula offered numerous opportunities for early development and progress in letter identification and numeracy, from which the group receiving the oddity instruction could profit with their superior abstractive abilities.

At about the same time as children typically develop an understanding of the oddity principle, they begin to *seriate* (Inhelder & Piaget, 1959/1964). That is, they understand that objects can be ordered along a dimension, such as height or width, from smallest to largest. Children first accomplish this by what Inhelder and Piaget (1959/1964) called the *method of extremum*. They select the largest item in a group, set it out, go back to the group and pick the largest item that remains, set it next to the first one they set out, go back to the group and pick the largest item that remains, and so on. (A child may also do it in the reverse order, starting with the smallest object.) If careful, children can build quite a long series in this way, and their procedure is very orderly. But they do not yet fully understand the relations between the items, as is demonstrated when they are offered a new middle-size object to put in the series. Despite the fact that it belongs in the middle of the series, they will place it at the end, where it obviously does not belong, as it is much larger or smaller than the last item. If the incorrectness of that choice is pointed out to them, they will put it at the other end and will be unable to think of any alternative. Southard and Pasnak (1997) provided a summary of the progression of approaches children develop in constructing a series and correcting it. The final stage in seriation on a single dimension is reached when children ultimately develop the ability to insert an object in its proper place within the order, which requires the child to relate the new object to the objects just larger and just smaller in the series (Piaget & Inhelder, 1968/1973).

For the current research, seriation instruction was added to oddity instruction to give the preschoolers who received cognitive instruction an advantage in both forms of abstraction. These two abilities normally develop at about the same time in an intertwined way. Strengthening both might produce a better result than strengthening one alone. Pasnak, Kidd, et al. (2007) and Kidd et al. (2008) have shown that 5-year-olds (kindergartners) who are at risk profit academically from instruction in oddity, seriation, and conservation. It seemed reasonable to attempt to teach 4-year-old preschoolers oddity and seriation, which develop somewhat earlier than conservation (Piaget & Inhelder, 1941/1974). We also wished to test more fully the assumptions that instruction in these forms of abstraction benefits preschoolers who are at risk in both letter identification and numeracy. Hence, an experimental design that involved a numeracy control group as well as a letters control group and a more traditional control group was used.

The selection of children as potential beneficiaries of the instruction was based on the recognition that even though children typically develop understanding of oddity and seriation without interventions, there are children whose progress has been affected by environmental factors. One such factor is poverty (Hart & Risley, 2003). Growing up in an impoverished household can affect children's cognitive development (Smith, Brooks-Gunn, & Klebanov, 1997). Although many children from families with low socioeconomic status are quite bright, many others function nearer to the floor of their cognitive potential than to its ceiling. They may have lacked cognitive instruction and enrichments, which often results in the Matthew effect, which, according to Stanovich (1986), results in ''the rich-get-richer and poor-get-poorer effect'' (p. 382). Such children may have the potential to function much better if they are helped to develop abstractive abilities that are natural for their ages, overcoming to some extent the lack of enrichment. Many children from households that are economically disadvantaged are enrolled in subsidized preschools, of which Head Start is the best known, and it was with such children that the intervention was tested. It was most likely to succeed with them because they were likely to have more room for improvement than children who were developing more typically.

Whenever children are taught new ideas, it is important to consider how easily they will be able to grasp those ideas. Are the concepts understandable with the cognitive abilities the children currently possess? Or are they not presently understandable but within the zone of proximal development? Or are the concepts potentially beyond that zone and over the children's heads? In the first case, even a single example may be sufficient to convey the ideas. Numerous demonstrations of the first case were cited by Son et al. (2008), who provided examples from their own studies. The zone of proximal development was made famous by Vygotsky (1978), and a large number of techniques conventionally used by educators work well enough in helping children to understand concepts that are just beyond their grasp. When still higher levels of abstraction are involved, considerable experimental work, both old (e.g., Gelman, 1969; Harlow, 1959) and new (Dixon & Bangert, 2004; O'Reilly & Munakata, 2000; Reeves & Weisberg, 1994), suggests that the best results are achieved when children experience many diverse examples of the principles being learned. These collections of multiple and variable examples, sometimes called *learning sets,* are effective in part because they improve executive function (Zelazo, Carter, Resnick, & Frye, 1997). Mastery of extensive exemplars allows children to learn to attend to salient features of the problems and engage necessary supporting behaviors (Gagné, 1968; Gagné & Paradise, 1961) and eliminate errors of engagement and behavior associated with their current executive functioning. Both processes are often very gradual (Gagné, 1968; Harlow, 1959). Beyond this, as Chalmers and Halford (2003) pointed out, just why such sets of numerous exemplars facilitate generalization within, and to some extent beyond, the range of the exemplars has never been satisfactorily explained. It is clear that use of the learning set is effective in producing both stimulus-specific learning and generalization to other problems as well as stimulus independence (responses that are not tied to the particular training stimuli or format). Because preschoolers who lagged significantly in understanding the oddity principle or seriation were to be selected for this experiment, learning sets were selected as the method for instruction.

An important characteristic of preschoolers, especially preschoolers who are low functioning, is that they are relatively difficult to engage in ''lessons,'' even when warmth and support is offered. They are motivated by and learn through play, as educators who specialize in early education have long attested (e. g., Copple & Bredekamp, 2009; Eisner, 1990; National Association for the Education of Young Children, 2009; Weininger & Daniel, 1992). This was anticipated by Vygotsky in his discussion of how to advance children's ability to think. ''In play a child is always above his average age, above his daily behavior, in play it is as though he were a head taller than himself' (Vygotsky, 1978, p. 129). Consequently, a method of structured play that was focused on a goal (Garrett, Busby, & Pasnak, 1999; Pasnak, Kidd, et al., 2007) was used to teach the oddity principle and seriation. Hence, this project was a field experiment in which preschoolers would be helped in developing two forms of abstraction that begin to develop at about age 4 years by methods that work well with preschoolers, and the effect on their cognitive development and learning of letters and numbers would be assessed.

That there are significant connections between verbal and quantitative achievements of diverse sorts, numeracy, seriation, and various measures of classification has been known for decades. The relations are both simultaneous and longitudinal and show up on both teacher-constructed and standardized tests, including the Metropolitan Achievement Test, Iowa Test of Basic Skills, Gates-McGinitie Reading Test, Primary Abilities Test, SAT composite, and many others (see reviews by Silliphant, 1983, and Waller, 1977; also Kingma, 1983, and Kingma & Koops, 1983). Whether achievement is more predictable from these basic cognitive abilities or from psychometric measures of intelligence and whether partialing one or the other out statistically changes the correlations much varies from one study to another (Waller, 1977). There was, in fact, some controversy as to whether psychometric intelligence and the abstractive abilities involved in oddity, seriation, and other concrete operations investigated by Piaget really differed or were merely different expressions of reasoning abilities that predict early school achievement (Glass & Stephens, 1980; Humphreys, 1980; Humphreys & Parsons, 1979; Stephens, McLaughlin, Miller, & Glass, 1972). Our approach with preschoolers was based on this close relationship. It was also based on the direct relationships between oddity, seriation (and conservation), achievement reported by other researchers, and the direct relationships between oddity and seriation reported more recently for older children by Pasnak, Kidd, et al. (2007) for letter identification and recognition and Kidd et al. (2008) for numeracy. Strengthening the types of thinking that predict achievement early in grade school might be expected to improve achievement in preschool.

HYPOTHESES

(a) One set of hypotheses was that the children instructed in oddity and insertion should outscore the other groups when subsequently tested on those constructs. (b) Another hypothesis was that the children instructed on letter identification and recognition should outscore the art and numeracy groups on a subsequent test of letter identification and recognition. (c) A third hypothesis was that the children instructed on numeracy should subsequently outscore the letters and art groups on a test of numeracy.

These hypotheses were directional. Other hypotheses relied on the fact that the Head Start day was filled with instruction related to early literacy and early numeracy. We hypothesized that the cognitive advantage that might result from the oddity and insertion instruction would enable the children receiving the cognitive instruction to (d) outscore the art and numeracy groups on letter identification and recognition and (e) outscore the letters and art groups on numeracy. These hypotheses were also directional.

The final hypotheses were nondirectional. The cognitive group would do the following: (f) outscore or be outscored by the letters group on letter identification and recognition and (g) outscore or be outscored by the numeracy group on numeracy.

METHOD

Participants

In late September, all 255 children enrolled in the seven centers of an urban Head Start program were screened with a 22-problem oddity test to determine how well they understood the oddity principle. The 72 who scored the lowest ($M = 9.49$, $SD = 4.19$) participated in the research. There were 35 girls and 37 boys; their average age was 53.26 months ($SD = 5.07$). All were from families that met federal poverty guidelines. They were ethnically and culturally diverse: 38% African American, 16% Hispanic/Latino, 31% Mideast Asian, 8% West African, and 8% other.

Design

The 72 children from seven centers and 18 classrooms were formed into quartets in each classroom. One child in each quartet was randomly assigned to receive the experimental cognitive instruction on oddity and insertions, a second to receive control instruction on letter recognition and identification, a third to receive control instruction in numeracy, and the fourth to receive control instruction in art. In this design, the effects of teachers and schools were neutralized for the children in the four conditions because each teacher and school had equal numbers of children receiving each type of instruction. All children in a quartet received the same number of individual 15-min instructional sessions from the same teacher.

Measures

Oddity test. Everyday materials—toys, spools, pencils, coins, beans, and so on—were used to make 24 oddity problems (2 practice problems, 4 color, 4 size, 6 form, and 8 orientation). Different objects were used in each problem. The two practice problems differed from each other in size, form, color, and kind of object. Color oddity problems consisted of four objects that were identical except that three were one color and one was a different color. For one problem, the odd object was white and the others black; for another problem, the odd object was black and the others white. For a third problem, the odd object was blue and the others yellow; and for the fourth problem, the odd object was yellow and the others blue.

Size oddity problems had four identically shaped objects. For two problems, one object was smaller than the others; for two problems, one was larger. Two form oddity problems each had three objects that were identical and a fourth that was also identical except that it was missing a piece. There were also two form oddity problems that each had three identically shaped objects and one that was different in its overall shape. Finally, two form problems were each composed of four objects having the same overall shape. One object in each set had a different internal detail.

There were two orientation oddity problems, each consisting of four identical objects: Three were placed right side up while the fourth was upside down, or vice versa. Two other problems had three identical objects in vertical orientations and one horizontal, or vice versa. Two problems had four identical objects with three slanting left (or right) at a 45-degree angle and the fourth slanting in the opposite direction. The last type of oddity by orientation had four identical objects with three facing left and the fourth facing right, or vice versa. The 22 nonpractice problems were presented to the children in a counterbalanced order so that no type of problem was presented any sooner or later than any other. This test was constructed specifically for this research. It was an expansion of the oddity test used by Pasnak, Kidd, et al. (2007) and Kidd et al. (2008); test–retest reliability of the earlier version has ranged from .76 to .93. The earlier test also produced modest but statistically significant ($p < .001$) correlations ranging from .27 to .31 with the Woodcock–Johnson III (WJ-III) Applied Problems measure of mathematics and a correlation of .41 with the 12-item Otis-Lennon School Ability Tests (O-LSAT) oddity measure. Research with a still earlier version yielded correlations of .76 with the Peabody Picture Vocabulary Test–R, .66 with the Peabody Individual Achievement Test, and .77 with Slosson Intelligence Test mental ages (all ps $< .001$), for children with an average mental age of 5 years, 5 months (Pasnak, Willson-Quayle, & Whitten, 1998).

Seriation test. The seriation test involved all new objects. Again, these were common objects (beads, ribbons, small toys, etc.) that children might commonly encounter. There were two sets of three objects each and two sets of four objects each. The children were to align the objects in each set from smallest to largest. There were two more sets of four objects. The children were to line up three objects from these sets and were then given the fourth object, which had been held back, to insert where it belonged in the series. There were two more sets of five objects (the children were given four to seriate and then inserted the fifth when it was offered), and two sets of six objects (the children were to form series of five and then insert the sixth object when it was offered). This test was constructed for the research reported by Pasnak, Kidd, et al. (2007) and Kidd et al. (2008); reliability has ranged from .71 to .84, and correlations with the WJ-III Applied Problems mathematics measure ranged from .27 to .36 ($p < .001$) in those studies. In the Pasnak et al. (1998) research, correlations for the seriation measure were .73, .70, and .78 with the Peabody Picture Vocabulary Test , Peabody Individual Achievement Test, and Slosson Intelligence Test, respectively.

WJ-III. The first 36 questions from Applied Problems measure of mathematics (McGrew & Woodcock, 2001) and a (numeracy) scale of the WJ-III were used for posttesting these preschoolers. This is one of the Family And Child Experiences Survey (FACES) tests approved for use with Head Start children, and it has a Kuder–Richardson reliability coefficient of .86. Mather and Gregg (2001) reported reliability coefficients greater than .80 for each scale. Convergent validity coefficients of .71 and .64 with the Diagnostic Assessment System, .68 and .70 with the Wechsler Individual Achievement Test, and .62 and .66 with the Kaufman Test of Educational Achievement are given for the verbal and quantitative scales, respectively, in the manual.

Stanford Early School Achievement Test 2 (SESAT). Early literacy was measured using the Letters and Words subscale from the SESAT (Technical Manual, 2003). This 40-problem scale measures phonemic awareness and has a Kuder–Richardson reliability coefficient of .82. The manual reports that content validity was assessed by a panel of experts and that median correlations with the O-LSAT were .62 . Chard et al. (2008) gave a validity estimate of .64.

Materials

Oddity instructional materials. Everyday objects were used to construct 20 form oddity problems. Three objects in each problem were identical, but one differed in shape. There were also 10 size oddity problems in which four objects were identical except that one was larger than the others; and there were 10 more size oddity problems in which four objects were identical but one was smaller than the others. Finally, there were 20 orientation problems, each consisting of four identical objects, one of which could be placed in a different orientation than the others.

Seriation instructional materials. New everyday objects were used to construct 15 three-object problems in which objects were identical shapes but three different sizes. There were 20 more problems in which there were four new identically shaped objects that varied in size and 15 problems in which there were five new objects varying in size. Finally, there were five problems with six new objects, five problems with seven new objects, and five problems with eight new objects. In each problem, objects were identical, except that they could be aligned from smallest to largest according to size.

Instructional materials for letters. Foam alphabet letters in both uppercase and lowercase were used to teach letter recognition and letter identification. New everyday objects were also used to construct letter bags. Each letter bag corresponded to a letter of the alphabet and contained approximately 10 small objects or pictures of objects that began with the corresponding letter as well as a copy of the letter in both uppercase and lowercase. The pictures and objects represented the various sounds associated with, for example, the letter *a*. For example, the first letter bag contained a capital *A* and a lowercase *a* and contained a toy apple, a picture of an ant, a toy alligator, a picture of an acorn, and so on. This allowed the objects in the bag to be used to develop awareness of the various sounds that correspond with the letter.

Instructional materials for numeracy. Foam numbers from 0 through 9 were used for number recognition and identification. Small objects that existed in multiple colors were used to create patterns and for counting. Replica clocks were also used in numeracy instruction.

Instructional materials for art. Coloring books, crayons, stickers, scissors, paste, clay, and other art materials found in the classroom were used for art instruction.

Procedure

Screening. Children were pretested with the oddity test. They were given a toy pony or dinosaur and told it was ''very hungry'' and ''wants to eat the different one.'' For each problem, the tester asked the child to feed his or her pony or dinosaur the ''different one.'' No input was given regarding the accuracy of choices. Children were encouraged through praise (e.g., ''Wow, great job, now your pony isn't hungry anymore'') regardless of their choices.

Instruction. The instruction began in early October and concluded at the end of March. This resulted in an average of 43.2 sessions ($SD = 12.6$). Instruction took place 3 days per week during a time in the morning when children customarily engaged in individualized activities. It was observed by project managers each day to maintain fidelity, and logs were kept of each child's progress.

Cognitive intervention: Oddity instruction. Children in the cognitive intervention group were shown four objects that differed only in shape. Their toy animal was asked to eat, stamp on, kiss, or otherwise identify the object that had the odd shape. Past experience with this preschool population suggested that it would be difficult and often frustrating for the children to attempt to learn the correct answer through trial and error, even with toys as props and a warm, encouraging adult as a support. Hence, instead of child-directed exploration, the instructor provided scaffolding that supported the child's learning. Essentially, the instructor started with a problem so easy that the learner was right on the first trial. On subsequent trials the problem was very gradually made more like the one the learner ultimately had to solve, but care was taken that changes were so gradual as to be almost unnoticeable and that the learner continued to be correct on every trial. In the current case, this involved giving the child many extra cues to the correct choice, such as placing it closer to the child, pointing at it, and, if necessary, blocking the child's effort to select an incorrect choice. As the child learned which object was ''odd,'' the extra cuing was gradually reduced until the child no longer needed it. In this way, learning of form oddity was accelerated and the children enjoyed always being right. When a child could solve all 20 form oddity problems easily without any extra cues, scaffolded experiences were provided for size oddity problems.

Problems in which the odd object was bigger than three otherwise identical objects were alternated with problems in which the odd object was the smallest. Again, extra cues to the correct choices were initially plentiful but were gradually reduced until a child could solve all 20 problems effortlessly without any extra cues.

Orientation oddity initially involved three identical objects in horizontal orientations and one in a vertical orientation, or vice versa. Or, three might be right side up and one upside down. Scaffolding was provided until a child could answer all 20 such problems without hesitation, in the absence of any extra cues. Then the 20 problems were presented again but with three of the objects slanting 45 degrees in one direction and the other slanting 45 degrees in the opposite direction. Again, extra cues were provided to identify the correct choices but gradually eliminated as the children mastered the problems. Finally, the 20 orientation oddity problems were presented again but with three objects facing left and one right, or vice versa. Scaffolding was provided as needed to speed learning and keep the children happy with their sessions. It was gradually eliminated as the children learned to solve all 20 problems.

Cognitive intervention: Seriation instruction. First the children were helped to solve 15 problems that had three objects varying in size. Scaffolding was provided as needed to make this fun and easy. The instructor would start with the objects nearly aligned and indicate where each should go. This extra cueing was gradually reduced until the child could accept the objects in a disordered heap and align them correctly. Ponies and dinosaurs pushed objects into the proper places to align them from smallest to largest and gave each other high fives, kisses, approving growls, and so on. When the animals were good at this, 20 four-object series were introduced one at a time, and each child's animal was taught to align them from smallest to largest. When this was easy, the instructor repeated the same 20 problems but would give the child only three of the objects, holding back the fourth, but perhaps leaving a large space in the series where the fourth object belonged. The instructor's animal would then deliver the ''forgotten'' object to the child's animal and help it place it in its proper place in the series. The large space for the forgotten object was gradually reduced until all three objects were equally spaced and the child had to make room for the fourth object to be inserted. The same procedure was involved when teaching a child (or rather, the child's animal) to form a series of four objects and insert a fifth, or to form a series of five, six, or seven objects and insert an additional object. As always, extra cues were provided when necessary but gradually eliminated until the child's performance was perfect without them. This instruction, like the oddity instruction, was potentially tedious for the children, because it lacked the variety of the letters, numeracy, and art conditions. However, the playful approach with interesting props and continual successes kept the children sufficiently engaged.

Letters intervention. Using the foam alphabet letters, children were first taught to recognize and identify the letters of the alphabet. Ponies and dinosaurs were used to ''eat'' the appropriate letter when the instructor asked the child to select the letter mentioned. Scaffolding was provided as needed to make this fun and easy. The instructor's animal would make the answer obvious to the child by giving the child extra cues as necessary. Children were also taught to name letters. Again, ponies and dinosaurs were used to assist children in properly naming the foam letters; the instructor's animal would ''eat'' a letter and ask the child which letter it was that the animal was ''eating.''

Once children had mastered the identification and recognition of letters, they were taught the sounds that the letters make using letter bags. The instructor presented the child with the letter that corresponded with the letter bag and then asked the child's animal to ''eat'' specific items from the bag that began with the target letter and sound. For example, the child would be shown the letter *C* and asked to find all of the items or pictures that begin like *candy*. The instructor's animal would make the answer obvious to the child by giving the child extra cues as necessary. Once the child's animal successfully identified the object, the instructor would say the name of the object while emphasizing the sound of the first letter and then would ask the child to do the same. Once the children had mastered the letter sounds, their animals were asked to sort the objects based on their beginning sounds from two different letter bags (e.g., *P* and *B* words) or within one bag if a letter was associated with more than one sound (e.g., *C* as in *candy* and *city*). The instructor's animal would make the answer obvious to the child by giving the child extra cues as necessary. By associating the letters with sounds, instructors provided the scaffolding needed for the children to develop an understanding of the alphabetic principle and the relationship between letters and sounds while at the same time developing their phonemic awareness. However, these preschoolers were not taught to spell the words or to contrast or blend sounds.

Numeracy intervention. Using the foam numbers, children were first taught to recognize and identify numbers from 0 through 20. Ponies and dinosaurs were used to ''eat'' the appropriate number when the instructor asked the child to select a number. The instructor's animal would make the answer obvious to the child by giving the child extra cues as necessary, making this enjoyable. Children were also taught to name numbers from 0 through 20. Again, ponies and dinosaurs were used to assist children in properly naming the foam numbers; the instructor's animal would ''eat'' a number and ask the child which number it was that the animal was ''eating.''

Once the child had mastered the recognition and identification of numbers, the instructor taught him or her to count by 5s and 10s. The children's animals were also asked to complete simple patterns—green, red, green, red, green—using objects that come in multiple colors, such as foam stickers and counting bears. Finally, children were taught to tell time using small clocks. Children were first taught what the different hands on the clock indicate and how to count by 5 for the minute hand. Then the child's animal was asked to identify the time that the instructor put on the clock. Finally, the child's animal was asked to move the hands on the clock so that it showed a specific time. Scaffolding was provided in all of this instruction to reduce frustration and speed learning. And because of the playful approach to learning, children remained engaged in the activities and stayed focused on these tasks that preschoolers were expected to master.

Art (control) instruction. The children who received art instruction would work with the instructor on creating an art project of their choice. They were given the option to draw, color or paint a picture, use stickers, paste cutouts on construction paper, fingerpaint, or use clay to make objects of their choice.

Testing. When the cognitive child in any quartet had mastered all of the cognitive instruction, the instruction of all children in that quartet was terminated. Each child was tested in late May with the SESAT literacy measure, the WJ-III numeracy measure, and the oddity and seriation tests in sessions separated by at least 24 hr. These tests were administered in an order counterbalanced by child and took about 10–15 min each.

RESULTS

Descriptive statistics are presented in Table 1. The children's scores ranged from 6 to 22 on the 22-problem oddity test and from 1 to 10 on the 10-problem seriation test.

Analytic Approach

Although each preschool contributed the same number of children from each class to each of the four conditions, some preschools had more classes than others, so hierarchical linear modeling (HLM; Raudenbush & Bryk, 2002) was conducted using HLM 6.0 software. The first step in these analyses involves computing an unconditional model for each outcome. Unconditional models have no predictors and only account for the nesting of the data in predicting the outcome. Consequently, an intraclass correlation coefficient can be calculated that represents the proportion of variance in the outcome due to the nesting. The next step in these analyses is to add predictors, including gender, age, oddity pretest score, and group assignment. In our case, because *children* were randomly assigned to cognitive, letters, numeracy, or art instruction, group membership occurred at the child level. Our final models can be represented by the following equations:

Level 1 Model

$$Y_{ij} = \beta_0 + \beta_1(\text{gender}) + \beta_2(\text{age}) + \beta_3(\text{oddity screening test}) + \beta_4(\text{cognitive}) + \beta_5(\text{literacy}) + \beta_6(\text{numeracy}) + r \tag{1}$$

Level 2 Model

$$\beta_0 = \gamma_{00} + u_0 \tag{2}$$

TABLE 1
Descriptive Statistics and Correlations for All Variables

Variable	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1. Gender	—										
2. Age (months)	.04	—									
3. Oddity screening test	.02	.16	—								
4. Cognitive group	.1	–.16	.03	—							
5. Letters group	.04	–.11	.02	–.32**	—						
6. Numbers group	.04	.2	.16	–.43**	–.30**	—					
7. Art group	–.12	.06	–.22	–.36**	–.25*	–.34*	—				
8. WJ-III	.12	.29*	.16	.20	–.27*	.21	–.20	—			
9. SESAT	.17	–.04	.18	.23*	.10	–.15	–.20	.39**	—		
10. Oddity final test	.06	–.01	.15	.43**	–.17	–.21	–.09	.27*	.29*	—	
11. Seriation test	.1	.16	.15	.34**	–.12	–.1	–.17	.42**	.40*	.38*	—
M	0.47	53.26	9.49	0.31	0.18	0.29	0.22	13.11	19.21	14.3	4.44
SD	0.5	5.07	4.19	0.47	0.39	0.45	0.42	4.96	5.79	4.1	2.66

Note. WJ-III = Woodcock–Johnson III Applied Problems; SESAT = Stanford Early School Achievement Test 2.
$^*p < .05$. $^{**}p < .01$.

The Level 1 equation models within-school variance based on children's characteristics. Thus, for child i in school j, the expected outcome, Y, is equal to the school average for that outcome, β_0; plus an effect for being male, β_1; plus an effect for age (in months), β_2; plus an effect for their oddity screening test score, β_3; plus an effect for being in the cognitive group, β_4; plus an effect for being in the literacy group, β_5; plus an effect for the being in the numeracy group, β_6; plus error, r. The Level 2 equation states that the preschool average, β_0, is equal to a grand average, γ_{00}, plus error, u_0.

Outcomes

Descriptive statistics and correlations for all variables included in the analyses are presented in Table 1. Significant negative correlations existed between group membership categories because being assigned to one group was by definition associated with not being assigned to another group. These simple correlations also revealed that three of the four outcomes correlated moderately with cognitive group membership.

Table 2 presents results from the HLM analyses. Unconditional models indicated that there were large disparities in the amount of variance attributable to the school. Between 0% and 31% of the variance in the outcomes was due to the school in which the children were enrolled. Intraclass correlation coefficients were only significant for letters as measured by the SESAT (.31) and seriation (.12). We conducted HLM for all outcomes for the sake of consistency. Results from nonnested models were nearly identical.

Results from the final models (with the art group being the comparison group) indicated that gender was not related to the outcomes, that age predicted WJ-III numeracy scores ($t(63) = 2.43$,

TABLE 2
Results of Hierarchical Linear Modeling Analyses

Variable	*WJ-III*			*SESAT*			*Oddity Test*			*Seriation*		
ICC	.02			.31***			.00			.12*		
Fixed Effects	*Coefficient*	*df*	*t*	*Coefficient*	*df*	*t*	*Coefficient*	*df*	*t*	*Coefficient*	*df*	*t*
Intercept	10.30***	6	6.83	16.80***	6	8.76	13.46***	6	13.16	2.75*	6	3.29
Male	0.80	63	0.72	1.80	61	1.49	0.53	63	0.59	0.61	64	1.08
Age (months)	0.28*	63	2.43	–0.02	61	–1.90	0.01	63	0.09	0.10	64	1.69
Oddity screening test	0.13	63	0.92	0.33*	61	2.21	0.19	63	1.86	0.08	64	1.06
Cognitive (vs. art)	3.67*	63	2.30	2.80	61	1.57	3.56**	63	2.78	2.69**	64	3.35
Letters (vs. art)	–0.58	63	–0.34	2.29	61	1.20	–0.85	63	–0.60	0.65	64	0.74
Numbers (vs. art)	3.14*	63	1.96	–0.18	61	–0.10	–0.57	63	–0.43	0.49	64	0.61
Random Effects	*Variance*	*df*	χ^2	*Variance*	*df*	χ^2	*Variance*	*df*	χ^2	*Variance*	*df*	χ^2
Intercept	3.08	6	13.81*	8.21	6	26.72***	0.00	6	3.19	1.41	6	22.42***
Level 1 effects	20.08			21.86			13.31			5.23		

Note. WJ-III = Woodcock–Johnson III Applied Problems; SESAT = Stanford Early School Achievement Test 2; ICC = intraclass correlation coefficient; coefficient = regression coefficient.

$^*p \leq .05$. $^{**}p \leq .01$. $^{***}p \leq .001$.

TABLE 3
Estimated Means for Each Group on the Four Outcomes

Group	*WJ-III*	*SESAT*	*Oddity*	*Seriation*
Cognitive	13.98^{bd}	19.60^{c}	17.02^{bcd}	5.44^{bcd}
Letters control	9.72^{ac}	19.09	12.61^{a}	3.40^{a}
Numbers control	13.44^{bd}	16.62^{a}	12.89^{a}	3.24^{a}
Art control	10.30^{ac}	16.80	13.46^{a}	2.75^{a}

Note. Superscripts denote $p < .05$. WJ-III = Woodcock–Johnson III Applied Problems; SESAT = Stanford Early School Achievement Test 2.

Significantly different from
[a]cognitive group;
[b]letters group;
[c]numbers group;
[d]art group.

$p < .05$), and that oddity screening test scores predicted SESAT scores ($t(61) = 2.21$, $p < .05$). Oddity screening test scores were not a significant predictor of the final oddity test scores, but this is not surprising given that a quarter of the children received an intervention that changed their subsequent oddity test scores from what the initial screening scores would predict.

Table 2 only indicates whether scores based on group membership were significantly different from scores for the art group. In order to evaluate our hypotheses, we conducted multiple comparisons whereby the reference group was systematically changed. This allowed us to test whether mean differences were statistically significant between all pairwise combinations of groups. Table 3 presents the results of the multiple comparisons tests. In this table, the mean for each group is presented for each outcome. Superscripts denote which of the groups are statistically different from one another for a given outcome. It is immediately evident that the cognitive group had the highest mean across all four outcomes, although differences were not always statistically significant. For the WJ-III numeracy measure, the cognitive and numeracy groups both scored significantly higher than the letters and art groups but did not differ appreciably from each other. For the SESAT Letters and Words measure, the means for the cognitive and letters groups were substantially higher than those for the numeracy and art groups; the difference between the cognitive and numeracy groups on this literacy test was statistically significant. For the oddity and seriation measures, the cognitive group performed significantly better than the remaining three groups.

DISCUSSION

The instructional method for teaching oddity and insertions to preschoolers worked well. These children did not have the difficulty experienced by the preschoolers Soraci et al. (1991) taught oddity by using operant methods. A major difference between that study and this one is the stimulus. Soraci et al. used banks of lights displayed in varying patterns—a stimulus unlike any with which the children had had previous experience. The preschoolers with whom they worked were allowed only to select the right display and did not interact significantly with an adult, being required to proceed on the basis of trial-and-error learning. Although operant methods are often very powerful, the playful, interactive approach used in the current research is more suitable for young children. Both of these factors may explain the relatively better outcome obtained here.

The performance on oddity of the Head Start preschoolers in the current research is a match for that of the preschoolers taught by Chalmers and Halford (2003), even though the more difficult dimension of orientation was added to the challenge faced by our preschoolers. Those researchers did use a learning set but had a mechanized presentation of two-dimensional stimuli. It appears that having real objects that the children could handle, teaching and correcting the child's toy animal rather than the child, and reducing the need for corrections through appropriate scaffolding makes the experience more engaging for young children and contributes to its success. The predilection of preschoolers for play rather than lessons is well documented by early childhood education specialists (e.g., Copple & Bredekamp, 2009; Eisner, 1990; National Association for the Education of Young Children, 2009; Weininger & Daniel, 1992). Hence, the instructional method used here, which is play but is very focused on teaching abstractions that children do not understand well at the outset, has much to recommend it.

That said, the means shown in Table 1 indicate that the principles involved in oddity and insertion were not completely mastered. This is the result usually obtained (Kidd et al., 2008; Pasnak, Kidd, et al., 2007). Learning abstractions that are more advanced than those children have developed on their own and then applying what was learned to new problems is challenging.

Nevertheless, the preschoolers who received the instruction in oddity and insertion scored about as well on the numeracy and letters tests as those who received 6 months of instruction in numeracy and letters. The scores of both the cognitive and numeracy groups on the WJ-III numeracy measure were appropriate for 5-year-olds in the first or second month of kindergarten (i.e., between K-1 and K-2). This is an excellent outcome for children from families living in poverty who were tested at the end of the preschool year. In contrast, the children in the literacy and art groups scored at the prekindergarten level—about the same as an average child at the age of 4.4 years. The picture is similar for the SESAT letters measure, which provides norms in terms of percentiles rather than age equivalents. The children in the cognitive and letters groups scored at the K-1 level—the 46th and 42nd percentiles, respectively, for kindergartners tested in the first quarter of the kindergarten year. Those in the numeracy and art groups scored at the prekindergarten level (the 29th and 25th percentiles, respectively).

The children who received the letters or art instruction scored below national norms on numeracy, and the children taught numeracy likewise scored below norms on the SESAT Letters and Words scale, despite the enrichment offered by their Head Start program. Such outcomes are likely when children have been raised in impoverished homes (Ryan, Fauth, & Brooks-Gunn, 2006). Although many do well, others lack the cognitive enrichment that would be found in many middle-class homes and consequently may not be functioning at the highest level of which they are capable. That is, they are probably functioning closer to the floor of their inherent abilities than to the ceiling. Consequently, they are less apt to understand and profit from preschool activities aimed at fostering knowledge of letters and numbers. At least, that is one of the assumptions on which this research was based. That the cognitive group matched the numeracy group in numeracy and the letters group in knowledge of letters and sounds testifies to the importance of the advantages in abstraction that group gained. These advantages appear to have enabled the cognitive group to better understand the typical preschool curriculum, which offered plenty of chances to improve in knowledge of letters and numbers. Hence, it is tempting to recommend that instruction aimed at improving preschoolers' abilities to abstract oddity and to seriate be added to preschool curricula. If sufficiently extensive to produce the improvements in these abilities shown by the children in the current study, it could assist children in understanding the lessons on numbers and letters provided by their classroom teachers.

It is important to recognize that the oddity and seriation instruction per se would probably have been ineffective in producing academic gains had the children not been enrolled in preschool or some comparable enrichment program. All children participated in age-appropriate literacy and numeracy activities offered by their classroom teachers to their whole class. An improved ability to recognize relevant differences (oddity) would not be helpful without significant instruction on what differences are relevant in distinguishing letters and numbers and understanding their properties. Likewise, improvement in understanding relations between concrete objects that vary in magnitude (seriation) is unlikely to result in better understanding of numeracy without classroom instruction in numeracy. The oddity and seriation instruction appears to have provided an effective supplement to classroom instruction that fostered improvement in both verbal and quantitative abilities but is not a stand-alone intervention, in spite of the conceptual improvements it engendered.

That the lessons used in the research on identifying and recognizing letters and their sounds were helpful to the children in the letters group is shown by the scores of that group, compared to those of the art and numeracy groups, when tested on the SESAT. This was essentially an analytic approach, and it is possible that another approach, such as a synthetic phonics approach (National Institute of Child Health and Human Development, 2000), would have been even more successful. Perhaps the letters group might have outscored the cognitive group. However, the level at which the letters group did score on the SESAT was a fine outcome for disadvantaged preschoolers.

Likewise, the control numeracy lessons were effective, as the numeracy group outscored the art and literacy groups when tested on numeracy at the end of the year. The virtue of the cognitive instruction is that it produced gains in both spheres equivalent to those produced by instruction aimed at and producing advantages in only one targeted sphere.

We should emphasize that there is no apparent direct connection between children understanding the oddity principle and seriation and knowing their letters or numbers. Advantages in the latter from competence in the former must result from a generally improved understanding of classroom lessons, which in turn results from better understanding of relevant differences and unidimensional ordering. The children who played the oddity games in this study learned to abstract key differences in shapes. They consequently were likely to have an advantage in comprehending the use of different two-dimensional letters of various shapes as abstract symbols to convey meaning and sounds. Likewise, numbers represent magnitudes, and the understanding that it is possible to put objects in order along a dimension of magnitude is directly related to understanding the differences in magnitudes that abstract symbols convey. This was found to be true specifically for the number line (Kingma, 1984), and Kingma (1983) also reported that there is a significant relationship between understanding the relationship involved in seriation and understanding reversal relationships in addition and subtraction. Preschool instruction assumes that children can appreciate relevant differences, understand magnitude relations, and much more. When children are good at these abstractions, they can profit much more from preschool instructional activities. Something of this sort must explain the relationships frequently observed between these expressions of cognitive development and a large variety of academic achievement measures (Silliphant, 1983; Waller, 1977).

Another issue with this research is the subject population chosen. These children had most of the school year to learn the concepts taught, and their mastery was incomplete. As Pasnak, Hansbarger, Dodson, Hart, and Blaha (1996) discovered, the intervention can work well for some children who are at the appropriate stage in cognitive development and not work at all for children who are too low functioning. In a study by Waiss and Pasnak (1993), it did not work well for children who already understood seriation and all but the most difficult forms of the oddity principle. Hence, research and applications based on the present research will succeed or fail depending on whether the participants are at an appropriate stage in their cognitive development. It is also true that any cognitive gains must be in place long enough for the children to profit from their new cognitive competence when receiving conventional classroom instruction. Thus, Pasnak (1987) found that there were no immediate gains on tests administered shortly after the cognitive intervention was concluded. Beginning the instruction in the fall and testing for results at the end of the school year is the procedure most likely to show the academic effects of experimentally induced gains in abstractive abilities.

These considerations illustrate some of the difficulties involved in efforts to improve academic performance and ability by improving cognitive ability. The appropriate cognitive abilities must be taught to the appropriate children at the appropriate level of cognitive development by the appropriate method at the appropriate time, and improvements will probably not be immediate (Pasnak, 1987; Pasnak et al., 1994; Waiss & Pasnak, 1993). What we have here is a population for which the present approach worked well; gains for a broader spectrum of children will probably require other approaches that are developmentally appropriate in both content and method as well as timing. For example, Kidd et al. (2008) used a more formal type of instruction for kindergartners, and Campbell, Gadzichowski, and Pasnak (2004) used a modified Wisconsin General Test Apparatus for an adolescent who had severe mental disabilities.

Future research may involve identifying just what types of instruction are most effective and efficient in the elementary school classroom and in preschools, which differ in both climate and mission, in the ratios of staff to children, and in the cognitive and behavioral development of the children. The effect of group size is unknown—Pasnak, McCutcheon, Holt, and Campbell (1991) taught kindergartners in groups of five or six—and it is an open question whether teaching these abstractive skills has to be a stand-alone activity or whether it can be integrated with other developmental domains. Pasnak, Madden, Malabonga, Martin, and Holt (1996) found that effects were still present a year later when kindergartners were taught oddity, seriation, and conservation, but whether that would be true for preschoolers remains to be seen. It may also be useful to explore teaching more advanced forms of classification and seriation, such as class inclusion and transitivity, multiple classification, and multiple seriation, to older children. However, the most pressing need may be to identify the mechanisms and processes by which improved understanding of the oddity principle and unidimensional seriation, singly and in combination, contributes to academic gains. The connections have not been investigated and have not received attention from theorists in cognitive development. It will likely be necessary to develop theory-guided measures of cognitive changes and possibly executive functions, as well as more detailed measures of verbal and quantitative gains than are provided by such general measures of academic progress as the SESAT and WJ-III scales, to make progress in this area.

Conclusion

A form of structured play can be effective in teaching the abstractions involved in seriation and the oddity principle to preschoolers whose families have economic disadvantages. Improvement in these cognitive abilities is accompanied by improvement in early numeracy and recognition and identification of letters. The effectiveness of the method used here may be limited to children who are at a stage of cognitive development similar to that of the children in this study, and the connections between the improved cognitive abilities and the improved academic abilities remain to be elucidated. However, the method and content of the cognitive intervention have promise for preschools serving children from low-income homes.

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