Learning Set Instruction in Seriation and the Oddity Principle for a Child With Severe Mental Disabilities

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Abstract: In a multiple baseline design, a teenager with a mental age of four years was taught two abstractions. One was the oddity principle (selecting the one object in a group which differs from the rest). The other was seriation (aligning objects along a continuum of size, and inserting new objects into their proper places in the alignments). These abilities demarcate the transition between preoperational and concrete operational thought, and are the earliest forms of purely relational responding. Learning sets of 80 oddity problems and 65 seriation problems were used to promote generalization. A “fade-out” procedure was used to make mastery of the problems as easy as possible. Combination of these techniques produced the first recorded success in teaching either the oddity principle or seriation to a child with severe disabilities, and may substantially reduce difficulty of helping many such children learn concepts at this level of abstraction.

Individuals who have mild mental disabilities become able to function at the concrete operational level of abstraction, with or without special instruction (McCormick, Campbell, Pasnak, & Perry, 1990). However, Inhelder’s (1968) research indicated that individuals who had severe disabilities did not develop any concrete operations. To date, there have been no published instances of individuals who have severe mental disabilities mastering even the earliest concrete operations – seriation through insertions into series, and classifying according to the oddity principle. These are forms of seriation and classification that are especially important. They depend on understanding the relations between objects, and are the first such understandings that are not tied to absolute qualities of the objects. Hence, they are the earliest forms of concrete operations – abstractions of relations between concrete objects – that children develop.

Individuals who have mental disabilities usually progress through the hierarchy of mental development that Piaget proposed in the same order as individuals without disabilities (Weisz, 1976; Weisz & Yeates, 1981; Weisz & Zigler, 1979). If there are no special interventions, their developmental ceilings vary with the extent of any disability. Individuals with similar mental ages usually function at similar stages in the Piagetian hierarchy whether they do or do not have disabilities. There have been only a few tests of whether Piagetian constructs can be taught to children who have mental disabilities, and all concerned children who had mild or moderate mental disabilities. Children described as “trainable” were taught the oddity principle (Klein & Safford, 1977, 1978). Children in self-contained elementary school classrooms were taught the oddity principle and to build a series and insert objects into it (Pasnak, Campbell, Perry, & McCormick, 1989; Perry, Pasnak, & Holt, 1992). Children with mild disabilities were taught conservation of number (Kern, 1983) and substance (Richards & Stone, 1970). There are no published attempts to teach such early concrete operations to children who have severe mental disabilities. The present project was an effort to teach a boy with severe mental disability the
oddity principle, to seriate objects according to size, and to insert objects into a series.

Use of the oddity principle is a form of classification that develops after hierarchical classification and precedes class inclusion. Oddity problems can only be solved on the basis of relations between the objects a child is considering. For example, if three beads are cubes and one is round, the round bead is “odd.” Conversely, if three beads are round and one a cube, the cube is odd. The relation might instead be in size (three large and one small, or vice versa), color, orientation, type, or any other dimension.

The key advance in thinking that the child has made is to recognize that the relation between the objects, rather than some absolute quality, is crucial. This understanding ordinarily develops at age four or five. A year earlier, the same child would have very persistently tried to solve such problems by learning the “right” shape, size, color, etc. in an absolute sense – always picking a round bead, or a large object, or a red one, or one having some other absolute quality, regardless of the nature of others in the set. It is exceedingly difficult to teach young (preoperational) children to respond to the relations involved in oddity, although the learning set method yields some progress (Ciancio, Rojas, McMahon, & Pasnak, 1991; Garrett, Busby, & Pasnak, 1990).

“Seriation” is a general term that means understanding the positions of objects along a continuum. This understanding is a key aspect of early cognitive development. It develops gradually, and by the time they are four years of age children have ordinarily learned to align objects from least to greatest along one continuum. This is typically accomplished by the “method of extremum” (Inhelder & Piaget, 1964/1959). All or nearly all children teach themselves to select the smallest object in a group, place it to start their series, then select the smallest object remaining in the group, place it next in the series, then select the smallest object remaining in the group, place it next in the series, then continue with this approach until all objects have been placed. If they are careful they can build quite a long series in this way. However, they do not have the understanding of the relations between objects higher and lower in the series that they appear to have. If given a new intermediate-size object to place in the series, they place it at the end instead of where it belongs in the interior of the series. If the error is pointed out, they may place the object at the other end, but are simply unable to find the place for it in the interior of the series. Leiser and Gillieron (1990) and Southard and Pasnak (1997) described the intermediate approaches children develop as they progress towards being able to insert an object into an existing series. Developing the ability to insert an object into a series requires another year or so, and represents a substantial cognitive advance over forming a series per se. It was defined at various times (Inhelder & Piaget, 1964/1959; Piaget & Inhelder, 1974/1941; Piaget & Szeminska, 1952/1941) as one of the earliest concrete operations, because it involves understanding the relations between neighboring objects in a series. Research by McCormick et al. (1990) with children who had mild mental disabilities showed that only the oddity principle precedes insertions into series in the development of concrete operations. Although McCormick et al. (1990), Perry, et al. (1992), and Pasnak et al. (1989) were generally successful in teaching this form of seriation to children who had mild or moderate mental disabilities, they had some failures with the lowest functioning children in self-contained special education classrooms. There has to date been no evidence that children who have a severe mental disability develop this form of seriation unaided, and no examples of it being taught to such children.

Nearly all teaching, whether children have or do not have disabilities, involves aiding them to apply the thinking abilities they already possess to new types of problems, situations or contexts. This is the central idea of “readiness,” or the “zone of proximal development.” Simple trial and error may work well, and skillful shaping or a variety of verbal techniques are very likely to succeed. However, teaching anyone to think at a higher level of abstraction than that person currently possesses, that is, beyond his “zone of potential development,” is extraordinarily difficult, (or according to Piaget, impossible). Special methods are essential to produce significant progress.

The basic thesis of this research is that early
forms of concrete operational thinking could be taught to children with severe disabilities by combining methods borrowed from comparative and educational psychology. One is the learning set approach (Gagne, 1968; Harlow, 1949). This method relies on representing the same abstract principle concretely in scores of problems that require active choices by the learner. Initial learning usually requires a great deal of shaping, is very slow, and seems to consist mainly of learning by rote the correct choice for each problem. However, as problem after problem embodying the same principle is mastered, error-producing tendencies are extinguished, supporting abilities are strengthened, and through induction the principle that governs successful choices is acquired. Stimulus independence develops as the principle becomes an abstraction not tied to the absolute qualities of the exemplars used in any particular problems. If there are enough problems in the learning set, and they are variable enough in appearance and details, the learner becomes able to recognize and apply that principle immediately to any new problem.

The slow initial learning and frustration inherent in a learning set might be reduced by the fade out procedure used in errorless instruction. The fade-out procedure starts by making the correct choice obvious to the learner by providing extensive extra cueing. Initially, extra cues should be so sufficient that no learning is required to make a correct choice. Teachers proceed by very gradually reducing extra cues, but are careful never to reduce them so much that correct choices are disrupted. If extra cue reduction is gradual and skillful enough, the learner solves the problem with fewer and fewer extra cues, until solutions are obtained for the problems that were desired all along. In this way, the learner eventually solves the problem without (theoretically) ever making an error, except through sheer inattention, even though the problem was far too difficult to be solved if presented without the fade-out procedure. The fade-out procedure is often combined with a fade-in procedure. Together, they are usually called “errorless learning,” and have been used with individuals who have various disabilities, including profound or severe mental disabilities (Day, 1987; Duffy & Wishart, 1987; Touchette & Howard, 1984).

In isolation, errorless learning techniques have not been a panacea (Ager, 1994; Duffy & Wishart, 1994; Jones & Eayers, 1992). Likewise, in isolation, learning sets have not been successful with every child (McCormick et al., 1990). However, both have also had successes (see above, and also Duffy & Wishart, 1987). The combination of a fade-out technique with the shaping and trial and error learning to learn inherent in learning sets might well be more powerful than any one technique. Since the fade-out procedure can readily be combined with the learning set approach, both were used to teach early concrete operations (abstractions or relational responses), rather than simple discriminations, to a boy who had a severe disability.

**Method**

**Participant**

The participant was a 14-year-old boy of Chilean extraction with severe mental disabilities due to Down syndrome. He attended a special center for children with severe or profound mental disabilities. His understanding of both Spanish and English was very limited, and he did not perform well enough on the Wechsler Primary and Preschool Scale of Intelligence (administered in Spanish, his best language) to permit calculation of a mental age. An estimate of approximately 3 years, 11 months was derived from the Diagnostic Ability Scales (DAS). His DAS scores were below 2 years 7 months on verbal measures but averaged 4 years 4 months on other scales. He was treated according to ethical guidelines of the American Psychological Association (1992), and his active assent was always sought. He enjoyed the procedure and always wanted to participate. He was affable, docile, and showed high mastery motivation in the experimental situation. His classroom teacher confirmed that he also showed these characteristics in the classroom. Readers who work with individuals who have severe disabilities will recognize the importance of these qualities to the success of any teaching effort.
Tests and instructional materials consisted of oddity and seriation problems constituted from many types of everyday objects. These included household, hardware, toy store, and grocery items ranging from beads and beans to screws and washers.

**Oddity test.** The oddity test consisted of five practice problems and 35 problems, each employing four objects. For eight oddity by type problems, three objects belonged to the same class and one to a different class, for example, three kinds of safety pins and a paper clip, or three different metal buttons and a coin. Eight shape oddity problems had three identical objects and one that differed only in shape, for example, three straight braces and a curved one, or three identical Barbie sandals and a Barbie high-heeled shoe. There were 12 size oddity problems that each had four objects that were identical in shape but one was either larger or smaller, for alternate problems. For example, there were three large Lego’s and a small one, three small Lego’s and a large one, three large butterflies and a small one, three small butterflies and a large one, etc. Finally, there were nine orientation oddity problems. Each of these had four identical objects. For the first three problems, three objects were presented right side up and the other upside down, or vice versa. For the next three problems, three objects slanted from 10 o’clock to 4 o’clock, and one from 8 o’clock to 2 o’clock, or vice versa. For the last three problems, three objects were pointed left and one right, or vice versa. The boy was always asked which object was pointed in a different direction.

**Seriation test.** The seriation test consisted of four practice problems, each having three objects of different sizes, and 26 test problems. These problems were all composed of ordinary objects. Five test problems each had three similar objects of different sizes (e.g., three padlocks, three nested cups, etc.) that were to be arranged order from largest to smallest. These were followed by four problems that each had four objects to be arranged in size order. The next five problems also had four objects, but only three were given to the boy for his initial seriation attempt. If he seriated these three correctly, the fourth object, (an intermediate-sized one) was given to him to insert into the series. There were six more problems for which he was first asked to seriate four objects and then to put a fifth where it belonged in the interior of the series. There were also five problems for which five objects were to be seriated and a sixth inserted into the series, and a final problem, which required seriating, six objects before inserting a seventh.

**Oddity learning set.** The oddity learning set had 20 shape problems, 20 size problems, 20 “type” problems, and 20 orientation problems. All were composed of ordinary objects that could be found in homes, out of doors, or in retail stores, and all were different from the objects used in the test.

For each shape problem, three objects were identical in shape and one different. The objects might or might not be different in color. The last six problems were reversals; for example, problem 15 had three round-headed bolts and a hexagonal-headed one, while problem 16 had three hexagonal-headed bolts and a round-headed one.

Each size problem had four objects that might or might not be the same color. They were otherwise identical except for size. Problems having three large and one small object were alternated with problems having three small objects and one large. Different types of objects were used in each of the first 14 problems, but the last six problems were reversals (e.g., three large and one small safety pin, and then three small and one large).

Each of the “type” oddity problems had three objects that were the same type of thing and one that was of a different type or class. The objects in a given problem were the same general size and shape, and might or might not be the same color. Examples are a walnut, a hazelnut, a peanut, and a brown rock, or a toy gorilla, a toy cow, a toy kangaroo, and a toy human. The last six problems were reversals (e.g., three different plastic numbers and a plastic letter, and then three different plastic letters and a plastic number).

Orientation oddity problems each had four identical objects. The first five had three objects placed vertically and one placed horizontally, or vice versa, with these orientations varying from trial to trial. The next ten problems had three objects slanting left and one slant-
ing right, or vice versa. For the last five problems, one object faced left, while the others faced right, or vice versa.

The learning set for seriation instruction was 65 problems composed from ordinary objects. The objects in each problem were similar in shape but formed a gradated series of sizes. There were 15 problems with three objects, 20 with four objects, 15 with five objects, five with six objects, five with seven, and five with eight.

**Design**

Because of the length and complexity of the instruction planned, a variant of the multiple baseline design was best suited for our investigation. In its classical form, this design consists of establishing baselines for two or more behaviors, then sequentially applying the treatment or experimental manipulation to each. Behaviors must be relatively independent and improvements from the baseline should be contingent upon when each was the target of the treatment. According to Evans (1985), if each of the behaviors changes in the anticipated direction primarily after the designated treatment has been administered to it, then the treatment is credited with the behavioral change.

As Barlow and Herson (1984) point out, many variations of this design are possible. Often there is only one behavior (dependent variable) rather than two or more, but the treatment is applied to different participants or in different settings. In other cases, it may be necessary to vary the manipulation to a greater or lesser extent to fit it to behaviors that are quite independent or different. For example, some differences in instruction are necessary to affect different social behaviors (Bates, 1980). If each variation in instruction is followed by significant change in the social behavior at which it was directed rather than in the other social behaviors, effectiveness of the instruction has been demonstrated.

In our application of this design, the dependent variable behaviors were quite independent, as forming objects into a sequence is not topographically similar to selecting the odd object from a group and requires a different form of abstract thought. The instruction for these two behaviors was similar but varied enough to accommodate differences in responses required from the participant.

**Hypotheses**

One experimental hypothesis was that significant changes would occur in seriation but not in oddity when the boy was instructed on seriation. The second hypothesis was that significant changes would occur in oddity but not in seriation when he was instructed on oddity.

**Procedure**

The boy’s understanding of the oddity principle and of inserting into series was initially measured with the oddity test and the seriation test. After this baseline testing a “fade-out” procedure was used 15 minutes per day, five days per week for four months, to teach him to form series and insert objects into the series. Verbal and gesture cues were combined with the fade-out procedure to shape the boy’s initial efforts at forming series. In this application of the fade-out procedure, a beam of light was focused on the spot where each object was to be put in turn, to guide his decisions. The light was very gradually dimmed as he mastered the first problem of seriating three objects, until he could seriate them accurately without the spotlight.

During this and all subsequent instruction, each correct decision was rewarded with a penny. These had great intrinsic reward value for this boy. He was taught to count five pennies he had earned to get a nickel, and five nickels to get a quarter, usually earning 25 – 50 cents per session. He kept this money and when his stash grew very large his teacher allowed him to use it to purchase snacks. It seemed clear, however, that he was happy to get the money even in the weeks before he was allowed to spend it. In general he was quite enthusiastic and cooperative during his experimental sessions.

The light was used again for the second problem, and gradually dimmed as he mastered this new problem until he could seriate the new objects without the aid of the light. This fade-out procedure of returning the spotlight to full strength with each new problem, using it to indicate where he should place the objects, and very gradually dimming it as he
learned how to seriate each set of objects, until he could dispense with it, was followed for all 15 3-object problems and all 20 4-object problems.

At this point he was able to seriate the 4-object problems easily. Insertions were taught by going back to the first 4-object problem and giving him only three of the objects to seriate. The fourth, which was the second or third largest of the series, was then given to him to insert. The classic error most children make before they develop the ability to insert is to place new objects at the end or beginning of the series. However, the beam of light was used to show clearly where the object should be placed in the series. The light was gradually dimmed as he became more and more adept at placing the object where it belonged in the series. When he was able to insert the object accurately, without guidance of the spotlight, the next 4-object problem was introduced. The light was returned to full strength and he was again given three objects to seriate, followed by the fourth to insert into the series with guidance of the spotlight. This fade-out procedure was continued until he could accurately insert a fourth object into a series of three for all 20 4-object problems. The same approach was used to teach him to insert a fifth object into a series of four for all 15 5-object problems, and similarly to build the series and insert an intermediate-sized object for the last 15 6-, 7-, and 8-object problems.

As is usually the case for learning sets, progress was slow in the beginning, but very rapid at the end. He did not need the aid of the spotlight for the last 15 problems, and progressed through them quickly. When, after 47 sessions, he had mastered all problems, the oddity and seriation tests were readministered.

Lack of funding caused a six-month lapse before instruction could be resumed. The oddity and seriation tests were readministered. Then a shaping procedure was used to begin instruction on the oddity principle. The four objects that constituted the first form oddity problem were placed in a line before the boy, the odd object was spotlighted, and he was helped, verbally and manually, to put his finger on it. He was rewarded with a penny, the objects were withdrawn, and then the objects were presented to him again with the positions of all objects changed. When his response to this task had been shaped, the spotlight was gradually dimmed until he could select the odd object without it. This procedure was repeated for each of 20 form oddity problems, then for 20 size oddity problems, then for 20 oddity by “type” problems.

Next, instruction on orientation oddity problems began by presenting the odd object in a horizontal orientation while the others were vertical, or vice versa. This is the type of orientation problem that children typically find the easiest. As always, the spotlight was used to guide correct decisions, and gradually dimmed until unneeded. When the boy had solved all 20 orientation problems with objects in vertical and horizontal positions, the problems were presented again with three objects slanted to the left and one to the right, or vice versa. When these had been mastered, the 20 orientation problems were presented again with three objects pointed left and one right, or vice versa. This kind of orientation problem is the hardest for children to master. When all of these problems could be solved without the aid of the spotlight, the oddity and seriation tests were readministered.

**Results**

The baseline (pretest) seriation score was 11.5%. Immediately after the seriation instruction his score was 69.2%. The improvement was significant, $z = 2.58, p < .01$. His oddity baseline score was 38.8%. He scored 58.3% on the oddity test immediately after the seriation instruction was completed. The difference between pretest and posttest was not significant, $z = 1.73, p > .05$. Thus, during the period he was taught seriation, he improved significantly on seriation but not on oddity.

His seriation score after the lapse of six months was stable at 73.1 %, still significantly better than the baseline ($z = 3.10, p < .01$), and his oddity score was also stable at 52.7%. Neither score was significantly different from those made immediately after the seriation instruction, $z = 0.25, p > .05$ for seriation and $z = 0.52, p > .05$, for oddity, respectively. At
the conclusion of the instruction on oddity his seriation score was again 73.1%. His errors on oddity problems were halved, so that his oddity score increased to 77.8% (z = 2.00, p < .05). Thus, during the period in which he was taught oddity, his seriation score remained stable but his oddity score improved significantly.

Discussion

There are many things, including familiarity with research personnel, apparatus, and tests, positive expectations, measurement change, regression, maturation, and other artifacts that can produce improvement from test to test. We suspect, for example, that this child already had some initial understanding of oddity (a chance score would be 25%), and that familiarity increased his score a little on both the oddity and seriation tests after working with the researchers for six months on seriation. The logic of the multiple baseline design is that such artifacts would produce significant gains on both dependent variables, not just the variable a child was taught. Evidence that the instruction per se had an effect is (1) the significant gain in seriation when seriation was taught, (2) the significant gain in oddity when oddity was taught, and (3) the absence of a significant gain in either construct when that construct was not taught. Apart from the difference in statistical outcomes, this child’s improvement on seriation after seriation instruction was three times the magnitude of his improvement on oddity. In contrast, after oddity instruction his seriation scores were unchanged while he reduced his errors on oddity problems by half. It is evident that the specialized techniques employed substantially improved his mastery of whatever relation was taught, above and beyond any gains due to extraneous factors. The pattern of his oddity scores before and after the seriation instruction shows, in contrast, effects of familiarity and other situational variables per se.

Pasnak et al. (1989) showed that the learning set employed here was by itself sufficient to teach seriation to children with mild or moderate disabilities, but was not sufficient for those who functioned at a lower level. Use of the fade-out procedure was probably crucial in the present research, which involved a boy whose functioning was at an even lower level. Variations on this approach can probably be used profitably to make many problems that involve discrimination much easier for children who have disabilities. Using a variable intensity spotlight in the present research was a matter of convenience. Many other techniques can be used to make a choice completely obvious and then progressively less so; the only limitation is the ingenuity of the teacher.

The fade-out technique as applied here is not far removed from ordinary scaffolding. It differs in principle only by (1) the initial step of making the child’s active choice one that is completely obvious to that child, and (2) insistence on approaching the final discrimination desired so gradually that the learner never makes any errors. In practice, a teacher’s impatience or over-optimism usually results in too rapid elimination of the faded cues and some errors occur, but in theory there need be none. In any event, the children experience consistent success, and eventually master problems that would otherwise be far over their heads. In Vygotsky’s terms, assisting a child to reach beyond his or her current capability is a way of stretching the zone of proximal development to reach beyond the putative level of potential development.

The fade-out method is part of a complex of procedures often called “errorless learning.” Errorless learning procedures have not always proven to be the most successful approach or even to be successful (Ager, 1994; Duffy & Wishart, 1994; Jones & Eayers, 1992). Part of the problem is that, as Ager (p. 156) pointed out, a variety of procedures that have quite different operational definitions are all lumped together under the term “errorless learning.” These include fading out an enhancement of the discriminative stimulus, as was done here, fading in a comparison stimulus, as Terrace (1963) originally did, verbal prompting, manipulating a learner’s hands, and other procedures designed to eliminate errors. Success of any teaching method depends on how well the method is suited to the behavior that is ultimately desired. The fade-out procedure with a spotlight was a good fit for the discrimination tasks that were to be mastered here. The boy gradually developed
good insight into it, and when a problem was well mastered he sometimes spontaneously took the spotlight and pointed it at the correct place or object, playing the role of teacher. It is difficult to see how a fade-out procedure involving a spotlight would be as successful in teaching something like brushing teeth or donning sweaters.

Shaping is a powerful tool, and should not be neglected in guiding a child’s initial responses, or responses to increases in task demands. It was important in this research for helping the child to understand what was wanted from him when he was first tested on seriation and on oddity, when seriation instruction began, when insertions were introduced, and when instruction on oddity began. Shaping and the fade-out procedure are a bit similar in purpose and execution, and are not at all incompatible. Both are methods of gradually leading the learner to the desired behavior(s) and require intuition and artistry on the part of the teacher. When failures occur, it may be because the method used was not used skillfully.

Even though such procedures can make mastery of a problem easy, the scores of problems of a learning set must be mastered, rather than just a dozen or so problems, in order to result in generalization of what was learned, especially generalization of an abstract principle. For educators, the issue with children who have severe mental disabilities is always to devise teaching methods that make better use of the intelligence the child has while evading any disruptive behaviors the child may display when experiencing frustration in learning situations. Shaping, the fade-out technique, and the learning set approach appear to be methods that can be combined effectively towards these ends, and should be part of any instructor’s armory.

Comparable gains on any concrete operation have never before been demonstrated for children who have severe mental disabilities. The question for developmental psychologists is why children should be taught any such thinking ability, when there are many useful things that might be taught. One answer is that mastery of any concrete operation helps a person understand many disparate events in the world around him or her. To understand the place of items on a continuum like size, and to be aware of where new items should go in a series, is to have a key tool for understanding the immediate environment. This child developed a substantially increased awareness of such relationships, which he understood even when presented with novel objects. That his newfound seriation ability did not diminish over the many months that elapsed between the instruction and the follow-up tests suggest that this ability was reinforced by his everyday experience, as is normally the case for children. This may be an advantage inherent in teaching natural thinking processes, which are more likely to be used routinely by the developing child than many other things which might be taught. The same advantage maybe inherent in coming to understand ways in which objects can be related via the oddity principle. This seems to be the first pure abstraction that children normally develop, and once grasped it may be reinforced continually by their interaction with their environment. There is the possibility that a fundamental cognitive ability like understanding such relations between objects or understanding relations within series might prove to be foundations for more advanced cognitive abilities. Can children who are helped to learn oddity and insertions into series be helped to learn more advanced concrete operations? Such issues await exploration.

References


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