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AUTHOR Berlin, Donna F.; White, Arthur L.
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ABSTRACT

The ability to recognize, extend, and relate patterns and sequences to numeric, figural, and word representations plays a prominent role in science education. This study provided validation information for an instrument to assess childrens' ability to recognize and extend patterns and sequence in different representational forms. A 57-item instrument, designed to measure spatial-symbolic information processing, was developed. The results of this data collection were subjected to principal components and factor analysis procedures to identify underlying constructs. Three factors were identified by the analysis and clarified by a varimax rotation and accounted for 28.6% of the variance of the responses. These factors were: (1) Numeric Patterns/Sequences; (2) Figural Patterns/Sequences; and (3) Word Concept Patterns/Sequences. Grade level effects were found on the first two factors. (11 tables, 13 references) (Author/YP)

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AN INSTRUMENT TO MEASURE SPATIAL-SYMBOLIC INFORMATION PROCESSING ABILITY

DONNA F. BERLIN
THE OHIO STATE UNIVERSITY AT NEWARK
NEWARK, OHIO

ARTHUR L. WHITE
THE OHIO STATE UNIVERSITY
COLUMBUS, OHIO

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ABSTRACT

AN INSTRUMENT TO MEASURE SPATIAL-SYMBOLIC INFORMATION PROCESSING ABILITY

The ability to recognize, extend, and relate patterns and sequences to numeric, figural, and word representations plays a prominent role in science education. This study is part of an ongoing process to develop measures of spatial-symbolic information processing. The potential contribution of this instrument to science education derives from three, related factors: patterns, spatial ability, and analytic/sequential versus holistic/simultaneous processing. Science instruction at elementary and middle school levels should involve hands-on activities and the use of pictures, drawings, and diagrams. Instruction should focus upon relating patterns and sequences in the classroom to the real world environment. This type of instruction relies upon spatial aptitude and the ability to apply analytic/sequential and holistic/simultaneous processing skills.

A 57 item instrument, designed to easure spatial-symbolic information processing was developed. This instrument has resulted from a series of validation studies since 1985. The instrument was administered to a sample of 165 third, fourth, and fifth graders from a small town/rural public school. There were 81 males and 84 females in the sample. The results of this data collection were subjected to principal components and factor analysis

procedures to identify underlying constructs. Cronbach's Alpha internal consistency reliability estimates were computed for five scales determined from previous studies and for three scales resulting from this factor analysis. Grade Level by Gender multivariate analysis of variance was computed to determine relationships of spatial-symbolic information processing, as measured by this instrument, with Grade Level and Gender.

Three factors were identified by principal components analysis and clarified by a varimax rotation. These three factors accounted for 28.6% of the variance of the responses. Items with loadings of 0.40 or greater were grouped to comprise three new scales. These scales (factors) were identified as: Factor 1 - Numeric Patterns/Sequences (Alpha = 0.87), Factor 2 - Figural Patterns/ Sequences (Alpha = 0.84), and Factor 3 - Word Concept Patterns/Sequences (Alpha = .95). The multivariate analyses of variance resulted in no significant Grade Level by Gender interactions and no Gender differences on any of the scales. Grade Level effects were found on four of the five original scales: Scale A (Figural Analogy), Scale B (Monotonic Progression), Scale D (Rule Application), and Scale E (Rule Identification and Application). Grade Level differences were also found for two of the three new scales: Factor 1 (Numeric Patterns/ Sequences), and Factor 2 (Figural Patterns/Sequences). The upper grade level subjects scored higher than the lower grade level subjects on the Numeric Patterns/Sequences scale. The Figural Patterns/Sequencing scale revealed differences between the third graders and both the fourth and fifth graders while the fourth and fifth graders were virtually identical.

These scales will help to obtain reliable measure of student abilities to recognize and extend patterns and sequences on tasks varying in representational forms (numeric, figural, and words) and representational levels (semiconcrete to abstract). This instrument will be valuable for detecting changes resulting from development of curriculum and learning activities designed to help students relate concrete and abstract understanding of concepts.

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AN INSTRUMENT TO MEASURE SPATIAL-SYMBOLIC INFORMATION PROCESSING ABILITY

Purpose. The purpose of this research is to develop and provide validation information for an instrument to assess childrens' ability to recognize and extend patterns and sequences in different representational forms (i.e., spatial and symbolic). This instrument is meant to have special relevance related to integrated uses of technology in science education. Due to the continual development of new technologies for education there is a need to better understand the role of different representational forms and visual processing of information in the learning of science concepts, processes, and skills. To move forward in this understanding, it is necessary to have accurate and precise instruments to measure the specific variables of interest.

Theoretical Basis. The potential contribution of this instrument to science education derives from three, related factors: patterns, spatial ability, and analytic/sequential versus holistic/simultaneous processing.

The ability to recognize and extend patterns plays a prominent role in science teaching and learning. "All of the sciences presume that the things and events in the universe occur in consistent patterns that are comprehensible through careful and systematic study." (American Association for the Advancement of Science, Project 2061, p. 6, 1989). Science can be defined as the search for patterns or regularities in natural and man-made environments.

There has been considerable research relating spatial ability to success in science courses and scientifically-related vocations (Smith, 1964). Studies have found that spatial ability is related to achievement in life science (Lord, 1985), physical science (Pallrand & Seeber, 1984; Siemankowski & MacKnight, 1979), and organic chemistry (Carter, LaRussa, & Bodner, 1987; Pribyl & Bodner, 1987; Small & Morton, 1983). For example, Pallrand and Seeber (1984) contend that the understanding of drawings and diagrams used to teach physics relates to spatial ability. In an extensive study involving 1648 science and engineering students, Carter, LaRussa, and Bodner (1987) found that scores on two spatial tests consistently contributed a small but significant amount to success on measures of performance in chemistry.

Other studies have focused upon the type of processing involved in science learning: analytic/sequential or holistic/simultaneous. In a recent article by Winn (1988), it was suggested that "science students are typically required to apply both types of processes to diagrams and to learn about both the element and how they are related to each other." (p. 377). This instrument provides opportunities to assess how students process figural and textual stimuli by requiring students to either attend to the elements in the series (analytic) or to the relationships among the elements (holistic).

It is generally agreed that science instruction at the elementary and middle school levels should involve hands-on activities and the use of pictures, drawings, and diagrams. This type of instruction relies upon spatial aptitude, visual processing, and the ability to apply both analytic/sequential and holistic/simultaneous processing skills in order to understand both elements and the relationships among the elements. The use of this instrument in the classroom may provide insight into experiences and training related to pattern recognition, spatial ability, and dual processing skills in order to enhance science achievement.

Design and Procedure. In this research design, pattern, and sequence are operationally defined as follows: (1) design - an arrangement of elements; (2) pattern - an arrangement of elements related by a qualitative rule (e.g., organizational, structural, spatial); and (3) sequence - an arrangement of consecutive elements arranged by a quantitative rule (e.g., numerical, temporal, ordinal).

The instrument used for data collection in this study was a revised version resulting from a series of validation studies by Berlin and White (1986), White and Berlin (1986), Berlin and White (1987), and Berlin, White, and Fraser-Abder (1987). The stimuli are presented in the form of geometric, figural, numeric, symbolic, and textual representations. The instrument consisted of 57 items with five scales identified from a previous instrument development study (Berlin & White, 1987). These scales are: Scale A - Figural Analogy, Scale B - Monotonic Progression, Scale C - Figural Sequences, Scale D - Rule Application, and Scale E - Rule Identification & Application. These scales and the number of items for each are listed in Table 1.

TABLE 1
Distribution of Items on Instrument Scales

Scales		Number of Items
(A)	Figural Analogy	13
(B)	Monotonic Progression	11
(C)	Figural Sequences	10
(D)	Rule Application	13
(E)	Rule Identification & Application	10
Total		57

These items were administered to a sample consisting of 165 third, fourth, and fifth grade children from a small town/rural public school. Table 2 includes the distribution of subjects by grade level and gender.

TABLE 2
Grade Level by Gender Distribution of Sample

	Grade Level			
Gender	3rd	4th	5th	Total
Male	33	24	24	81
Female	22	35	27	84
Total	55	59	51	165

Data Analysis. The following statistical analyses are reported: (1) descriptive statistics for each scale; (2) principal components analysis for identification of underlying constructs; (3) Cronbach's Alpha internal consistency reliability coefficients; and (4) two Grade Level by Gender group comparisons using a 2x3 factorial multivariate analysis of variance with the five original scales as dependent variables in the first analysis and the three scales resulting from the factor analysis in this study as the dependent variables in the second analysis.

Results and Conclusions. The overall Cronbach's Alpha internal consistency estimate for the total score on the instrument was 0.89. The reliabilities for the total scale and the five original scales are given in Table 3.

TABLE 3
Original Subscale Reliabilities

Scale	Number of Items	Alpha
Total	57	0.89
Figural Analogy	13	0.79
Monotonic Progression	11	0.64
Figural Sequences	10	0.51
Rule Application	13	0.86
Rule Identification & Application	10	^.45

A principal components analysis resulted in a three factor solution which accounted for 28.6% of the variance. Table 4 includes the eigenvalues and percent of variance for the first 19 factors using the default value for an eigenvalue greater than or equal to 1.00.

TABLE 4
Factor Analysis Eigenvalues and Percent of Variance

FACTOR	EIGENVALUE	% OF VARIANCE
1	9.48	16.6%
2	3.76	6.6%
3	3.05	5.4%
4	2.21	3.9%
5	2.06	3.6%
6	2.00	3.5%
7	1.74	3.1%
8	1.69	3.0%
9	1.65	2.9%
10	1.49	2,6%
11	1.47	2.6%
12	1.42	2.5%
13	1.32	2.3%
14	1.26	2.2%
15	1.24	2.2%
16	1.16	2.0%
17	1.13	2.0%
18	1.07	1.9%
19	1.01	1.8%

Using a combination of the Scree method and the percent of variance accounted for by individual factors equal to or greater than 5% the first three factors were isolated for varimax rotation. The results of this rotation are given in Table 5.

TABLE 5
Varimax Rotation Factor Loadings

Item	Factor 1 Loading	Item	Factor 2 Loading	Item	Factor 3 Loading
* D10	.67	B02	.64	D03	.91
B08	.66	A03	.63	D04	.88
D12	.65	A05	.59	D02	.88
A11	.64	C07	.58	D05	.87
D13	.63	A06	.57	D01	.86
D11	.63	A04	.53		
A12	.62	B01	.53		
D09	.53	B03	.53		
D07	.51	C01	.52		
B07	.50	A01	.52		
D08	.49	B09	.48		
B05	.47	A02	.47		
B06	.47	A08	.47		
D06	.46	C08	.44		
A10	.41	C02	.40		

* The letters identify the scale and the numbers identify the item number within the scale.

Three factors were identified: Factor 1 - Numeric Patterns/Sequences, Factor 2 - Figural Patterns/Sequences, and Factor 3 - Word Concept Patterns/Sequences. The number of items and Cronbach Alpha estimates for these three scales are given in Table 6.

TABLE 6
Principal Components Factors Reliabilities

Scale	Number of Items	Alpha
Factor 1 - Numeric Patterns/Sequences	15	0.87
Factor 2 - Figural Patterns/Sequences	15	0.84
Factor 3 - Word Concept Patterns/Sequences	5	0.95

The items on Factor 1 provide the subject with a pattern or sequence of numbers. A number is left out and the subject's task is to determine what number is missing. One of the highest loading items on Factor 1 was:

_____, 11, _____, 27, 35, 43

The items on Factor 2 provide the subject with a pattern or sequence of shapes and they are asked to determine what is missing or comes next. One of the highest loading items on Factor 2 was:

What comes next?

The items on Factor 3 provide the subject with a random arrangement of three words representing concepts which can be ordered from the smallest to the largest. One of the highest loading items for Factor 3 was:

rope, string, thread   Order from smallest to largest.

These items were scored from 0-3 based upon the number of pairs of words ordered correctly.

TABLE 7

Multivariate Analysis of Variance (Five Original Scales)

Analysis	F	p
Grade Level by Gender		
Multivariate (Wilks)	.79	.641
Univariates		
Scale A	.22	.802
Scale B	.04	.959
Scale C	.32	.724
Scale D	1.71	.184
Scale E	1.43	.243
Gender		
Multivariate (Wilks)	.53	.751
Univariates		
Scale A	.06	.810
Scale B	.06	.811
Scale C	.33	.565
Scale D	.17	.685
Scale E	1.33	.250
Grade Level		
Multivariate (Wilks)	3.69	.000
Scale A	10.67	.000
Scale B	8.74	.000
Scale C	1.49	.230
Scale D	6.08	.003
Scale E	12.08	.000

TABLE 8

Multivariate Analysis of Variance (Three Factor Scales)

Analysis	F	p
Grade Level by Gender		
Multivariate (Wilks)	.55	.773
Univariates		
Factor 1	.39	.677
Factor 2	.17	.842
Factor 3	1.33	.267
Gender		
Multivariate (Wilks)	.31	.820
Univariates		
Factor 1	.19	.667
Factor 2	.11	.746
Factor 3	.44	.509
Grade Level		
Multivariate (Wilks)	5.66	.000
Univariates		
Factor 1	17.03	.000
Factor 2	8.23	.008
Factor 3	1.21	.300

The Grade Level by Gender multivariate and univariate analyses of variance comparisons are given in Tables 7 and 8. There were no significant Grade Level by Gender interactions or Gender main effects for any of the original scales or the new scales (factors) resulting from the factor analysis. In previous work by White & Berlin (1987), there were effects indicating that girls scored higher than boys on tasks involving words. Although no significant interaction resulted for Word Concept Patterns/Sequences it can be seen from Table 11 that the third grade female subjects showed a tendency to do better than the boys. There were Grade Level main effects on the original scales: Scale A (Figural Analogy), Scale B (Monotonic Progression), Scale D (Rule Application), and Scale E (Rule Identification & Application) and there were also Grade Level main effects in the second analysis on the new scales: Factor 1 (Numeric Patterns/Sequences) and Factor 2 (Figural Patterns/Sequences). The upper grade level subjects scored higher than the lower grade level subjects on the Numeric Patterns/Sequences scale. The Figural Patterns/Sequencing scale revealed differences between the third graders and both the fourth and fifth graders while the fourth and fifth graders were virtually identical. The means and standard deviations for Factors 1, 2, and 3 are given in Tables 9, 10, and 11.

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TABLE 9

Means and Standard Deviations for Factor 1

Gender		Grade Level 3	4	5
Male	M	6.4	8.7	11.3
	SD	4.0	3.9	3.3
	N	33	24	24
Female	M	7.4	8.7	11.1
	SD	3.3	4.1	3.8
	N	22	35	27
	M	6.8	8.7	11.2
	N	55	59	51

TABLE 10

Means and Standard Deviations for Factor 2

Gender		Grade Level 3	4	5
Male	M	11.6	13.0	13.8
	SD	3.4	2.7	2.3
	N	33	24	24
Female	M	11.8	13.0	13.2
	SD	3.4	2.7	2.6
	N	22	35	27
	M	11.7	13.0	13.5
	N	55	59	51

TABLE 11

Means and Standard Deviations for Factor 3

Gender		Grade Level 3	4	5
Male	M	12.1	13.4	14.3
	SD	5.0	3.8	2.7
	N	33	24	24
Female	M	13.9	13.2	14.0
	SD	2.4	4.6	3.6
	N	22	35	27
	M	12.8	13.3	14.1
	N	55	59	51

<u>**Interpretations and Recommendations.**</u> The three resulting factors from the factor analysis represent numeric, figural, and words (verbal) embodiments of patterns and sequences. These scales are reliable (Alphas = 0.87, 0.84, and 0.95) measures of student abilities to recognize and extend patterns and sequences across semiconcrete to abstract representational levels. The spatial-symbolic information processing instrument should be useful to both the classroom teacher and the educational researcher. The test can be used by teachers to determine elementary and middle school students' pattern recognition ability (numeric, figural, and word concept) and make inferences concerning their analytic/ sequential and holistic/simultaneous modes of processing. This should allow researchers to explore the influences of activities on the development of the abilities to comprehend patterns and sequences. These scales will help to obtain reliable measures of student abilities to recognize and extend patterns and sequences on tasks varying in representational forms (numeric, figural, and words) and representational levels (semiconcrete to abstract). This instrument will be valuable for detecting changes resulting from development of curriculum and learning activities in science designed to help students relate concrete and abstract understanding of concepts.

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