

## Research Note

# CONTENT ANALYSIS AND INTRATEST PERFORMANCE PROFILES ON THE COLUMBIA AND THE TONI

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This research note presents the results of a content analysis of the Columbia Mental Maturity Scale and the Test of Nonverbal Intelligence (TONI). We also compared the intratest performance of a selected sample of language-impaired (LI) and MA-matched normal language children on these two tests. These analyses are an extension of Johnston's (1982) report on the Leiter. The content analysis revealed differences in the nature of perceptual and conceptual items on the Columbia and the TONI. Consistent with Johnston's findings, the intratest comparisons revealed no significant group differences. LI and normal-language children performed significantly better on the perceptual-type items than the conceptual-type items. The predominance of perceptual items was particularly evident in the TONI.

**KEY WORDS:** cognition, language-impaired, nonverbal, content analysis, assessment

Nonverbal intelligence tests play an important role in research and clinical assessment of children with specific language impairments. In research, one of the criteria used to select language-impaired (LI) children is age-level performance on nonverbal intelligence tests (e.g., Stark & Tallal, 1981). Nonverbal intelligence tests are used clinically as a measure of general cognitive functioning. Performance on these tests is also an excellent prognostic indicator of future academic performance. In fact, in a 10-year follow-up study of young speech- and language-impaired children, Aram, Ekelman, and Nation (1984) found that nonverbal intelligence, as measured by the Leiter, was the best predictor of academic performance. The most frequently used tests of nonverbal intelligence are the performance scale on the WIPSI (Wechsler, 1967) and the WISC-R (Wechsler, 1974), the Leiter International Performance Scale (Arthur, 1952), the Columbia Mental Maturity Scale (Burgemeister, Blum, & Lorge, 1972), and the Test of Nonverbal Intelligence (Brown, Sherbenou, & Johnsen, 1982).

Several years ago, Johnston (1982) performed a content analysis of the Leiter International Performance Scale. Johnston's item analysis indicated that test items fell into one of two groups according to the types of cognitive processes they entailed: (a) perceptual items that required the recognition only of physical resemblance, and (b) conceptual items that required knowledge of spatial, numerical, or classificatory relations. For the first 12 subtests, representing ages 2-4, there was only one conceptual task. Of the 16 subtests from ages 5-8, nine were conceptual in nature. Overall, 65% of the subtests through age 8 were perceptual tasks.

In addition to the content analysis of the Leiter, Johnston questioned whether LI children would show the same intratest patterns as normally developing children. Johnston hypothesized that language-impaired children would show different performance profiles from their normal peers by

performing proportionately better on the perceptual items than on the conceptual items. Subjects were 16 language-impaired and 16 normally developing children ranging in age from 4:4 to 5:5. The LI children were matched for chronological age (CA) and mental age (MA) to the language-normal children. The results did not substantiate Johnston's hypothesis. The LI children earned their normal-range Leiter IQs primarily by passing perceptual-type items, but so did the normal children. Although this finding is not surprising given the predominance of perceptual items in the age range studied, 4 LI children actually performed better on the conceptual items. Only 1 normal child performed better on the conceptual items.

Given the important role that nonverbal intelligence plays in research and clinical assessment of LI children, the purpose of the present study was to examine the content and intratest performance profiles of two other frequently used tests of nonverbal intelligence: The Columbia Mental Maturity Scale (henceforth referred to as the Columbia) and the Test of Nonverbal Intelligence (TONI). The content analysis will provide information about the particular cognitive abilities each test taps for a certain age level. For the intratest analyses, the performance of MA matched LI and normal children will be compared to determine whether both groups arrive at their normal-range scores in the same manner, as was the case on the Leiter.

## ITEM ANALYSES OF THE TONI

The TONI provides a measure of nonverbal intelligence in children as young as 5:0 years of age. The test is normed through adulthood. Like the Leiter, the TONI consists of items that demand primarily perceptual processes and those that demand primarily conceptual processes. As defined earlier, perceptual items require only the recognition of physical resemblance, whereas con-

ceptual items require the use of spatial, numerical, or classificatory knowledge (Johnston, 1982, p. 292). Using these definitions, four independent judges, the two authors and two doctoral students in speech-language pathology, classified each item on the TONI as a perceptual or conceptual item. Agreement was 94% on the TONI. Differences occurred on three items in each test. These differences were resolved through discussion.

Of the 50 items on the TONI, 15 or (30%) were found to be perceptual in nature; the remaining 70% of the items were conceptual. An example of a perceptual item is A1, where the child has to find a right angle triangle that matches the three stimulus items. An example of a conceptual item is A18, where the child has to recognize the pattern of shapes (triangle, circle, square) that occur inside another shape in each row of items. Almost all of the perceptual items occurred early in the test. In fact, the first 13 items on the test were perceptual. The other perceptual items were #23 and #37. A 5-year-old child would obtain an IQ score of 128 by responding correctly to the first 13 perceptual items. For a 6-year-old, the corresponding IQ score is 109, and for a 7-year-old it is 98. It is not until a child reaches the age of 11 that IQ falls below 85. Thus, most elementary-school children do not have to pass any of the conceptual items to obtain normal range IQs on the TONI.

An important characteristic of the TONI is that all of the items portray visual configurations. The test contains no pictures of objects (e.g., trees, boats, etc.) that tap prior classificatory knowledge, and although number is occasionally varied (e.g., item #32), knowledge of numerical relations is never required to select the correct answer. All of the items on the TONI require simple perceptual matches or prior spatial knowledge.

## ITEM ANALYSIS OF THE COLUMBIA

The Columbia provides a measure of nonverbal intelligence for children ranging in age from 3:6 to 9:11. The test consists of 92 cards containing 3-5 items. For each card, the child has to point to the particular item that does not belong. For example, if a picture contained two cups and a knife (item #1), the child should point to the knife. In order to select the different item, it is necessary to notice the similarity among the other items on the card. Although this similarity can be based on perceptual features, the "odd-one-out" format requires some classificatory processing. In this sense, the entire test requires conceptual processing. Johnston, however, defined a conceptual item as requiring *prior* spatial, numerical, or classificatory knowledge. Although all of the items on the Columbia require some classification, they do not necessarily tap prior conceptual knowledge. For example, a child could use prior knowledge of cups and knives to select the correct answer. But it is also possible for the child to note the physical resemblance of the two cups and select the knife because it does not look like a cup. Without asking the children how they solved each item, it

is not possible to determine the extent to which prior conceptual knowledge influenced responses.

With these points in mind, judges were instructed to classify an item as perceptual if it was possible to respond correctly by recognizing physical similarity. Physical similarity was defined as including spatial transformations and physically similar but not necessarily identical members of the same category. For example, item #19 has three lemon-shaped figures with different orientations and a circle. Item #12 has three different kinds of beds and a dresser. Several items were classified as perceptual if they required finding two pairs of similar pictures in order to determine the one that did not belong. Item #22, for example, has two ducks, two trees, and a girl. Using these criteria, the four independent judges agreed on 96% of the items. Disagreements were again resolved through discussion.

Table 1 presents the item classification of the 92 items on the Columbia. Of the 92 items, 36 were classified as perceptual (39%) and 56 (61%) were classified as conceptual. The relative proportion of perceptual items was slightly higher on the Columbia than it was on the TONI. As with the TONI, the majority of perceptual items occurred early in the test. The first 20 items were perceptual, whereas only two of the last 44 items and all of the last 25 items were conceptual. As can be seen in Table 1, there is considerable variability in the types of perceptual and conceptual items on the Columbia. The Columbia, like the Leiter, has items tapping classificatory, numerical, and spatial knowledge.

Further examination of the perceptual items showed that almost half (44%) included common objects. In a typical object item, the correct answer could be determined using a conceptual knowledge (dogs and cats are not the same) or physical similarity (dogs do not look like cats). About 31% of the items involve distinctions based on physical resemblances of visual configurations. For example, item #30 contains four identical shaded squares and a picture with

TABLE 1. Distribution of Columbia items.

	<i>Item numbers</i>
Perceptual items	
Common objects (16/36, 44.4%)	1, 3-10, 12, 13, 22, 27, 31, 42, 67
Visual configurations (11/36, 30.6%)	2, 11, 15, 17, 18, 20, 26, 30, 33, 37, 45
Spatial transformations (7/36, 19.4%)	14, 16, 19, 35, 40, 48, 58
Numerical similarity (2/36, 5.6%)	25, 32
Conceptual items	
Classificatory (27/56, 48.2%)	21, 23, 24, 28, 34, 38, 39, 44, 47, 49, 52-57, 61, 63, 65, 69, 70, 72, 76, 80, 84, 89, 90
Spatial (19/56, 33.9%)	29, 41, 43, 46, 50, 59, 60, 62, 64, 66, 71, 73-75, 77, 79, 82, 88, 91
Numerical (10/56, 17.9%)	36, 51, 68, 78, 81, 83, 85-87, 92

different shaded squares. All of these items except #20 portrayed visual configurations rather than objects. Item #20 contained four rabbits with ears pointed upward and one rabbit with ears bent. About 20% of the items required a spatial transformation, typically a rotation (e.g., #19 described above). The remaining two perceptual items included numerical distinctions. For example, item #32 had four single chicks and one pair of chicks.

Further examination of the conceptual items found that almost half (48%) required prior classificatory knowledge. For example, item #44 contains a picture of a hat, glove, foot, shoe, and hand. To determine that the hat doesn't belong, a child must know that a glove goes on a hand and a shoe goes on a foot. Prior spatial knowledge is involved in 34% of the conceptual items. Item #46 contains three pictures with a small red circle inside a geometric shape and a fourth picture with the circle outside the shape. In order to select the correct answer, a child must know something about topographical relations. Numerical knowledge is tapped in 18% of the conceptual items, most of which occur in the latter part of the test. For example, four of the pictures on item #68 have four colored dots in varying visual arrays whereas the remaining picture has five dots.

## INTRATEST PERFORMANCE OF LI AND NORMAL CHILDREN

### *Subjects*

From previous studies involving LI and MA-matched normally developing children, we had data available on 40 LI and 42 normally developing children who had been administered either the TONI or Columbia as part of the subject selection criterion. These studies addressed various aspects of cognitive and linguistic processing (Kamhi & Catts, 1986; Kamhi, Catts, Mauer, Apel, & Gentry, 1988; Kamhi & Koenig, 1985; Kamhi, Nelson, Lee, & Gholson, 1985; Nelson, Kamhi, & Apel, 1987). The TONI was administered to 18 LI and 14 normal-language children ranging in age from 5:9 to 9:4 years. The mean age of both groups was 7:6. The mean MAs of the LI and normal-language groups were 7:5 and 7:7, respectively. The Columbia was administered to 22 LI and 28 normal-language children ranging in age from 3:2 to 7:0 years. The mean CAs and MAs ( ) of the LI and normal-language groups were 5:2 (5:0) and 4:9 (5:1), respectively. There were 18 girls in each group. All of the LI children performed within normal age limits on these measures of nonverbal intelligence.

The LI children were diagnosed by a certified speech-language pathologist as having an oral language impairment based on standardized tests and linguistic analyses of conversational samples. Among the standardized tests used were the Peabody Picture Vocabulary Test (Dunn, 1965), the Test of Language Development (Newcomer & Hammill, 1982), the Expressive One-Word Picture Vocabulary Test (Gardner, 1979), the Developmental Sentence Analysis (Lee, 1974), and the Northwestern Syntax Screen-

ing Test (Lee, 1969). (Specific information about which tests children were given is provided in each study.) In order to be considered language impaired, a child had to perform at least 1 year below mental age level. In many cases, children performed below the 10th percentile on each of the tests administered. All of the children were receiving speech-language therapy at the time of testing. Although some of the children were dialectal speakers, dialectal variations played no part in the classification of the children as language impaired. None of the children showed any evidence of emotional disturbance or physical defects, and all passed a hearing screening within 6 months of testing. Hearing thresholds were 20 dB HL (ANSI, 1969) or better between 500 and 4000 Hz.

The normal-language children were obtained from the same elementary schools or, in the case of the younger normal children, from preschools that approximated the socioeconomic status and racial characteristics of the LI children. In general, the children came from middle-class homes, and the samples were racially mixed. The normal-language children were given the same clinical battery as the LI children. In all cases, they performed significantly better than the LI children on the clinical measures.

### *Procedures and Scoring*

The Columbia or the TONI (Form A) was administered to each subject individually by a graduate research assistant who had previous experience with each test. Testing took place in a nursery school, clinical, or educational setting. Standard testing procedures were followed. On the Columbia, there are no basal or ceiling levels. The examiner presents all of the cards in one of the eight levels (A through H). The number of cards in each level ranges from 51 to 63. On the TONI, the basal is five correct and the ceiling is three out of five incorrect. Test forms were independently re-scored by a second independent judge. Interjudge reliability was 98.5%.

Two measures were calculated for each test: percent correct for perceptual-type items attempted and percent correct for conceptual-type items attempted. Because the conceptual items occurred at the more advanced levels on both tests, one would expect more errors on these items. On the TONI, however, 6 LI children reached ceiling levels before attempting a conceptual item and 9 of the remaining LI children and 10 normal-language children attempted less than five conceptual items.

### *Results and Discussion*

Means and standard deviations for the percent-correct data for the TONI and the Columbia are presented in Tables 2 and 3. The data were first transformed using arc sine transformations. The transformed data were analyzed by two  $2 \times 2$  repeated-measures analyses of variance corresponding to group and item type. These analyses revealed significant main effects for item type [TONI— $F(1,30) = 187.8, p < .001$ ; Columbia— $F(1,48) = 265.9,$

TABLE 2. Mean percent-correct and standard deviations for the perceptual and conceptual items on the TONI.

Group	Perceptual items	Conceptual items
Language-impaired		
Mean	87.1	16.2
SD	16.7	24.1
Normal-language		
Mean	80.0	13.9
SD	26.1	17.2

TABLE 3. Mean percent-correct and standard deviations for the perceptual and conceptual items on the Columbia.

Group	Perceptual items	Conceptual items
Language-impaired		
Mean	81.6	46.8
SD	17.3	7.5
Normal-language		
Mean	82.0	49.9
SD	12.9	16.8

$p < .001$ ], but no significant effect for group [ $F(1,30) = .87$ ,  $p > .10$  (TONI);  $F(1,48) = 1.25$ ,  $p > .10$  (Columbia)]. The interactions were also not significant, [ $F(1,30) = .87$ ,  $p > .10$  (TONI);  $F(1,48) = .02$ ,  $p > .10$  (Columbia)].

The percent-correct data for the TONI and the Columbia were essentially similar for the perceptual items. Normal and LI children correctly responded to at least 80% of the perceptual items. For the conceptual items, however, the two tests differed considerably. On the TONI, both groups of children responded correctly to fewer than 20% of the conceptual items. In fact, the total TONI score for the average normal and LI child consisted of 11 correct perceptual items and only one correct conceptual item. This is not surprising given the early predominance of perceptual items and the age of the children tested. On the Columbia, in contrast, children responded correctly to about 50% of the conceptual items. Both groups of children averaged 25 correct perceptual items and 19 correct conceptual items. An examination of the specific items passed uncovered no specific items that a majority of one group passed and the other did not.

These analyses of the TONI and Columbia indicate that the two tests are measuring somewhat different knowledge in the age ranges sampled. The TONI is essentially a one-dimensional test for children in the early elementary school years because all of the early items are perceptually based. In contrast, the Columbia scores reflect both perceptual and conceptual abilities. Although the early items on the Columbia are also predominantly perceptual, these early items are targeted for 3 1/2-year-old children. In the present study, the average age of the subjects given the TONI was 7:6 years compared to 5:0 years for children given the Columbia. Despite this 2 1/2-year age difference, the Columbia still had a higher proportion of conceptual items than the

TONI. If the Columbia were given to 7:6 year-old children, the proportion of conceptual items would be even higher because the first item given is #28. Only eight perceptual items remain on the test after this point.

## GENERAL DISCUSSION

The content analyses and the intratest comparisons presented in this research note and Johnston's (1982) study illuminate important similarities and differences among the TONI, the Columbia, and the Leiter. Each test evaluates nonverbal intelligence and contains items that can be reliably categorized as perceptually or conceptually based. The TONI is the most unidimensional of the three tests because all of the items involve visual configurations that require perceptual matches or prior spatial knowledge. In contrast, the Leiter and Columbia tap classificatory and numerical knowledge in addition to spatial knowledge. The Leiter and the TONI have response formats that allow subjects to select correct responses based on straightforward physical resemblance. The Columbia's "odd-one-out" response format precludes using straightforward physical resemblances to select the correct answer. Of the three tests, then, the Leiter contains the most diverse set of items because these items tap a range of conceptual knowledge and include simple perceptual matches.

The intratest comparisons between LI and normal-language children were consistent across the three tests. Both groups of children earned their normal-range TONI, Columbia, and Leiter IQs by correctly answering primarily perceptual-type items. Importantly, LI children performed as well as the normal children on the conceptual-type items, indicating that both groups achieved their age-appropriate MA levels by responding to the same proportion of perceptual and conceptual items.

The lack of intratest differences between the two groups indicates that the content analyses provides an accurate reflection of the relative proportion of perceptual and conceptual items answered correctly at a particular age. As shown in this study, young school-age children answered very few conceptual items correctly on the TONI, but on the Columbia, they averaged 25 correct responses to conceptual items. On all three tests the relative proportion of conceptual items increases with age, but the specific age when conceptual items predominate differs among the three tests. On the Leiter and Columbia, conceptual items become prevalent around the 5-year level, whereas on the TONI they do not become prevalent until the 10-year level.

Future studies might examine children's intratest performance on two or more tests of nonverbal intelligence. In our clinical experience, we have come across several preschool LI children who have had no success on the Columbia, but performed at age levels on the Leiter. We have attributed these differences to the "odd-one-out" response format on the Columbia. However, these clinical cases might be isolated instances and, therefore, not be representative of the larger group of children who

perform at essentially the same level across different tests of nonverbal intelligence.

We began this paper by noting that nonverbal intelligence tests play an important role in research and clinical assessment of children with specific language impairment. It is important to remember, however, that despite the age-level performance of these children on nonverbal intelligence tests, they are not cognitively intact. For one, they have a language impairment, and language is, after all, a cognitive (mental) activity. In addition, there is a rich body of literature documenting other cognitive deficiencies in LI children in areas such as symbolic play (Roth & Clark, 1987; Terrell, Schwartz, Prelock & Messick, 1984), mental imagery (Johnston & Weismer, 1983; Kamhi, 1981; Savich, 1984), short-term memory speed and capacity (Kirchner & Klatzky, 1985; Sininger, Klatzky, & Kirchner, 1989), constructive inferencing (Weismer, 1985), and discrimination learning (Nelson, Kamhi, & Apel, 1987). Cognitive deficiencies such as these are difficult to reconcile with the view that LI children have normal intelligence.

A solution to this puzzle, as noted by Johnston (1982), involves the nature of intelligence tests and cognition. One tradition of intelligence testing holds that intelligence is essentially a unitary or monolithic phenomenon, and any task that involves thinking provides a measure of intelligence. A second perspective is that intelligence is multifaceted, such that different tasks measure different types of intelligences or cognitive abilities (e.g., Gardner, 1983). This latter perspective offers a solution to the puzzle, namely, that nonverbal intelligence tests tap different cognitive functions from those in which the LI child shows difficulty (Johnston, 1982). In short, LI children have particular cognitive strengths and weaknesses. Their cognitive strengths are best reflected by measures of nonverbal intelligence, whereas their cognitive weaknesses are most evident on tasks that tap linguistic knowledge and verbal short-term memory processes.

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