Diagnosing Students' Errors From Their Response Selections in Language Arts

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Abstract

This set of studies examined the consistency of student response patterns on a test of language arts, as a first step toward designing a computerized adaptive test to diagnose errors. A diagnostic domain-referenced language arts test was designed so that the choice of response would immediately point to a specific misconception in pronoun usage. This direct correspondence between error and diagnosis was designed to facilitate classroom instruction and remediation. Analysis of students' response choices on matched items and analysis of students' rationales for selecting their responses, however, showed that student behavior was not consistent and could not be used to diagnose specific errors. These findings raised questions about the possibility of using students' response patterns to identify the source of their errors.

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Introduction

The studies reported here were part of a project designed to develop a computerized adaptive test with a built-in program to diagnose errors in language arts, a subject matter area not explored in this way before. Specifically, the test was intended to uncover students' erroneous rules of usage to guide instruction and remediation in the classroom. As a first step in this process, a language arts test was developed and modified to assess the consistency of student response patterns and, consequently, the feasibility of using the test for diagnosing students' misconceptions.

The work of Brown and Burton and colleagues and Tatsuoka and colleagues shows that analysis of response patterns can be used successfully to diagnose students' errors in arithmetic. Brown and Burton (1978; see also Brown & VanLehn, 1980) use the answers to multiple-choice items to determine the bugs (erroneous rules) that students exhibit in solving arithmetic problems. Their work recognizes that students can have misconceptions and still give correct answers to some or even most items. Furthermore, different misconceptions will lead to different numbers of right and wrong answers and also to different pattern specific responses. From the specific patterns of responses, Brown and Burton can determine a student's particular bug or bugs. The drawbacks to their approach, at present, are that the process is very complex, requires fairly large numbers of items, and has been applied to quite restricted domains, namely addition and subtraction of whole numbers.

The work of Tatsuoka and Birenbaum (Birenbaum & Tatsuoka, 1982,

1983; Tatsuoka & Tatsuoka, 1983; Tatsuoka, 1983) is similar to that of Brown and Burton in that the pattern of responses is of central concern. With modified scoring of arithmetic items, specifically taking into account the absolute value and the sign in the addition and subtraction of signed numbers, Tatsuoka (1983) uses item response theory to calculate the likelihood of each bug. As in Brown and Burton's work, students' erroneous rules can lead to different patterns of right and wrong responses across items, making the process of diagnosis complex.

The studies presented in this report tried to expand diagnosis of erroneous rules to another, novel subject matter domain, language arts, which is broader than the domains of addition and subtraction used previously, and to design a test that could easily be used in the classroom for diagnosing misconceptions. Specifically, a test was designed to diagnose erroneous rules of pronoun usage. The test featured two major simplifications in its approach to diagnosing errors: (1) a misconception could lead only to an incorrect response, and (2) for parallel or matched items, a misconception would lead to the same incorrect response. Most importantly, the choice of response would immediately point to the misconception a student held. This approach to diagnostic testing could easily be adapted to a computerized setting giving the teacher a listing of the misconceptions for each student or for groups of students. This information could then be used to guide instruction and remediation.

The approach outlined above depends on consistency in student behavior; namely, that students do hold systematic misconceptions which they apply consistently to items of the same kind. If students do not consistently make the same kind of error, then it would be difficult, if

not impossible, to identify their misconceptions. This paper describes the design and administration of a domain-referenced test in language arts and examines the consistency of student responses to test items. In addition to examining the response choices, the study also used introspective recall to investigate the consistency of students' reasoning.

Method

Development of the Test

The decision about test content was guided by language arts teachers who were asked to indicate the kinds of grammar problems that students exhibited most frequently at the upper elementary grade levels and the areas in which a diagnostic test would be most helpful. The most common response was pronoun usage, and thus the original diagnostic test developed in this project measured that domain. Discussions with language arts experts and examinations of language curricula and textbooks showed that four content factors represented an important domain of pronoun usage: pronoun rule (nominative, three types of objective, possessive), pronoun form (relative--who or whom, non-relative), pronoun number (singular, plural), and pronoun person (first, third). A fifth factor represented the cognitive complexity of the item, here based on whether students had to use the context of a reading passage to determine the correct pronoun. For one level of cognitive complexity, the pronoun was embedded in a single sentence and the referent was given. For the other, the pronoun was embedded in a short paragraph and students had to use the context to identify the referent.

The original test developed to represent the entire domain of

pronoun usage had 92 items: 2 parallel (or matched) items for each of 46 combinations of the five factors. The matched items in a pair had identical grammatical structures, comparable vocabulary, and often had similar content.

Matched items also had the same distractors, representing common student errors related to rule, form, number, and person. A few exceptions were pairs of items in which the referent for the pronoun was male in one item and female in the other item. (Students did not have any difficulty inferring the correct gender, so the fact that one item called for a male pronoun and the second item for a female pronoun did not influence student performance.) For example, if the first item in a matched pair called for the pronoun "him", one of the distractors would be "he"; similarly, the correct answer for the other item would be "her" and one of the distractors would be "she". Distractors with different genders appeared only once in a matched pair of items; all other distractors for both items were identical. For the majority of matched items on the test (62%), all five response alternatives were identical.

By design, then, students who held erroneous rules of pronoun usage were expected to give the same response (or comparable responses) to both items. An example pair of matched items is the following:

(1) David, _____ the coach had given another chance, worked very hard all summer.

(2) The toddler, _____ the grandfather had given cake, was covered from head to toe with frosting.

In the above example, a student who responded "who" (incorrect pronoun rule: nominative instead of objective, a common error) was expected to

give the same incorrect response to the second item. This response would indicate incorrect pronoun rule, but would indicate correct pronoun form (relative). Similarly, students giving the answer "he" to the first item were expected to give "he" (or "she"; a toddler could be female) for the second item, indicating incorrect pronoun form (non-relative instead of relative), but correct pronoun rule (nominative).

The following example involves pronouns embedded in a paragraph:

(3) Mr. and Mrs. Roberts were on their way to the airport when Mr. Roberts realized that he had left his calculator at home. Fortunately, Mrs. Roberts loaned _____ her calculator.

(4) Julia and Sandy were on their way to the game when Sandy realized that she had left her pompoms at home. Fortunately, the drill coach loaned _____ some extras.

In this example, students making an error in the first item were expected to make the same error in the second item. Students giving the answer "he" in the first item (incorrect pronoun rule: nominative instead of objective) were expected to give the answer "she" to the second item. In this way, it would be relatively straightforward to identify students' misconceptions about pronoun usage. In the latter example, giving the answers "he" and "she" would indicate incorrect pronoun rule (nominative vs. objective), but would indicate correct person (third), correct form of the pronoun (non-relative), and the ability to determine the correct referent for a pronoun embedded in a paragraph. Similarly, giving the answer "them" to both items (which a few students did, thinking that the pronoun referent was the first two people named in the paragraph) would indicate difficulty determining the correct referent for pronouns embedded in a paragraph, but would indicate correct form (non-relative).

These inferences about students' misconceptions could then be used to guide instruction and remediation.

Analysis of student performance on the original test (generalizability analysis--see Cronbach, Gleser, Nanda, & Rajartnam, 1972--and analysis of variance) showed that students performed similarly on singular and plural pronouns and on first and third person pronouns, but performed differently on nominative and objective pronouns, on relative and non-relative pronouns, and on embedded and non-embedded pronouns. (For a complete description of these analyses and results see Webb, Herman, & Cabello, 1983.) Consequently, a subset of 16 items was selected from the original test to represent all combinations of nominative and objective pronouns, relative and non-relative pronouns, and embedded and non-embedded pronouns. For each of the 8 combinations of these pronoun variations there were 2 matched items, as described above. All pronouns were singular (rather than plural) and in the third person (rather than first). This 16 item test is the focus of the present set of studies.

Test Administration

Sample. The test was administered to three samples of sixth-grade students (n=79, n=26, n=21) from schools in an inner-city school district. The schools are located in a low- to middle-SES area with a high rate of transiency and a mixed population (90% Hispanic, 6% Black, 2% Asian, and 2% non-minority whites). All students were classified by the district as Fluent English Proficient.

Procedure. Test administration varied for the three samples. For

the 79-student sample (hereafter called Study 1), the test was administered conventionally in groups. Each item had five alternatives: one correct and four distractors. Students were permitted to ask the test administrator about difficult vocabulary, but were not permitted to ask other questions or consult with anyone else.

For the other two samples of students, the test was administered individually. After each item, students were asked to explain why they selected their response (introspective recall). Rationales given included indicating the correct referent of the pronoun, or characteristics of the correct referent such as gender or number. Sometimes students could not give a reason or could only give a vague reason such as "It sounds good". These responses were not classified as rationales for the analyses.

The only difference between the two latter administrations was the response format. For the 21-student sample (Study 2), the same multiple choice format was used as in Study 1. For the 26-student sample (Study 3) a multiple-choice format was not used. Instead, students were asked to construct their response choices. The purpose of the varied formats was to determine whether providing students with alternative responses influenced the consistency of their response selections or the consistency of their rationales for selecting responses.

Results

Consistency of Students' Response Selections

The data on consistency of students' response selections for Studies 1, 2, and 3 are presented in Tables 1, 2, and 3. The numbers without

parentheses are the proportions of students in each sample who gave each combination of correct and incorrect responses in a matched pair of items: both items correct, both incorrect with the same error, both incorect but with different errors, and one item correct and the other incorrect.

Prior to examining the data in each table, statistical tests were performed to determine whether the performance of the three samples was comparable. The statistical test used here was the chi-square test comparing proportions across independent samples (see Fleiss, 1981, p.139). This test was computed for each of the 36 proportions in the tables. Due to the large number of statistical tests being conducted (36) a significance level of .01 was used instead of the conventional level of .05. Only two of the 36 tests were significant. For these two comparisons, post hoc analyses were conducted to determine the precise differences between studies (see Fleiss, 1981). First, a higher proportion of students gave the correct answer to both non-relative, embedded, objective items in Study 3 than in Studies 1 and 2. Second, a higher proporiton of students gave the correct answer to both relative, embedded, nominative items in Studies 2 and 3 than in Study 1. The small number of significant comparisons, coupled with the inconsistent directions of the comparisons, suggests that the three studies are comparable. It was concluded that the method of test administration and the format of the items had little effect on student performance.

As can be seen in Tables 1 through 3, students were rarely consistent in their responses to each pair of matched items.

If students were consistent in their conceptions about pronoun usage, they would have given the same or comparable responses (correct or incorrect) to both items in a matched pair. The number of students giving different incorrect answers to the items or giving the correct answer for one item and the incorrect answer for the other item would have been small. In all three studies, however, the proportions of students giving inconsistent responses were substantial. In Study 1, 44% of the students, averaging over all pairs of matched items, were inconsistent in their responses to matched items (15% making different errors + 29% giving one correct response and one incorrect response). The average percentages of inconsistent responses for Studies 2 and 3 were 37% (5% + 32%) and 28% (11% + 17%), respectively. These data suggest that substantial numbers of students did not hold systematic misconceptions of pronoun usage.

Examination of a few of the inconsistent responses across matched items suggests that such performance is unlikely to occur if students hold systematic misconceptions about pronoun usage. First, consider the second pair of items given in the section of this paper entitled "Development of the Test." The most common instance of one correct and one incorrect response was "them" for the first item (incorrect referent) and "her" for the second item (correct). Second, the most common combination of different incorrect responses was "them" for the first item (incorrect referent) and "they" for the second item (incorrect pronoun referent and incorrect rule: nominative vs. objective). It is difficult to imagine that student use of systematic erroneous rules for

pronoun usage would produce these combinations of responses. For embedded items, rules for selecting the response, other than misconceptions about the type of pronoun or pronoun referent, were considered. An obvious example is a student selecting the first response alternative (for the multiple choice format) that would be grammatically correct if the sentence with the pronoun were not embedded in a paragraph. While there were a few isolated instances of this behavior, it could not explain most student behavior.

By far, the most important information for diagnosing misconceptions is the proportion of students making the same error on both items in a matched pair. Students making the same error on matched items very likely are using an erroneous rule consistently to determine the correct pronoun. From the error made, it is easy to identify the erroneous rule, and the teacher can use this information accordingly. The proportions of students making the same errors on matched items were low, however: 15% in Study 1; 9% in Study 2; 18% in Study 3. Even among individual pairs of matched items, the proportions were rarely large enough to be of practical value in the classroom. One of the few large proportions, for example, was the 54% of students in Study 3 who gave the same incorrect answer to the two items measuring knowledge of objective, relative pronouns embedded in a paragraph. All of these students gave the answer "who" instead of "whom", showing that they had a misconception concerning the nominative and objective cases of relative pronouns. Large proportions occurred too infrequently, however, to warrant such detailed testing. Overall, then, the data in Tables 1 through 3 show

that the analysis of incorrect responses would be beneficial only for a small number of students and only for a few items on the test used here. Analyzing incorrect responses probably has little value for the classroom, at least in pronoun usage.

Consistency of Students' Rationales for Selecting Responses.

It was hoped that students who made consistent response choices (both correct or the same incorrect choice both times) would be more consistent in the rationales for their selections than would students who were inconsistent in their responses (different incorrect responses or one correct and one incorrect response). Such results would make it reasonable to use students' rationales to make inferences about their particular misconceptions.

The data on consistency of students' rationales appear in Tables 2 and 3, where the numbers in parentheses show the proportions of students giving each response combination who also provided the same rationale for giving each response. For example, the first entry in Table 2 shows that of the 95% students who gave the correct answer to both items in this pair, 15% of them gave the same rationale for both items. In terms of numbers of students, 95% of 21 students is 20 students; and 15% of 20 students is 3 students. Similarly, for the third entry in the first column, of the 29% of students who gave the correct answer to both items in this pair, 17% of them were consistent in the rationales for selecting their response. In terms of numbers of students, 29% of 21 students is 6 students; and 17% of 6 students is 1 student. The percentage of students giving consistent rationales, therefore, often corresponds to very small

numbers of students in Tables 2 and 3.

As was done for the consistency of students' response selections, statistical tests were performed to determine whether the students in Studies 2 and 3 differed in their consistency of rationales. None of the statistical tests was statistically significant, showing that the two samples were comparable.

As the data in Tables 2 and 3 show, students who gave consistent answer choices did not present more consistent rationales than students who did not give consistent answer choices. Averaging over the two studies across all pairs of matched items, only 33% of the students who gave consistent answer choices provided the same rationale for both items in a pair. By comparison, 27% of the students who gave inconsistent answer choices across matched items offered the same reasons for making their choices. The difference between percentages is not statistically or practically significant.

In summary, neither students' wrong answer choices nor their rationales for giving their answers were consistent enough in the present set of studies to warrant analyzing patterns of students' responses in the classroom. Such analyses would produce little information to help teachers diagnose students' misconceptions about pronoun usage.

Conclusions

There are several possible explanations for the lack of consistent student responses in the present set of studies. First, students may have held systematic misconceptions about pronoun use but behaved

randomly or carelessly on the test. If this hypothesis were true, the high degree of inconsistency would suggest that students were frequently careless or random in their responses on many items. The procedures of the two studies using introspective recall, however, tend to refute this hypothesis. The one-to-one testing situation most likely facilitated attention, and the fact that students were required to give a rationale for their responses should have encouraged care and thoughtfulness. Students often gave rationales for selecting their responses, even if their rationales were not consistent across items.

Second, the items may not have been sufficiently parallel in structure to elicit consistent student behavior. That is, features of the items, such as vocabulary, content, and grammatical structure, may have led students to use different strategies for selecting pronouns in different items. Given the careful control of vocabulary, content, and grammatical structure in the matched items, however, this hypothesis also seems unlikely.

One qualification of the hypothesis just mentioned concerns the grammatical structure of the items. While items were carefully matched on surface structure, it was difficult to ensure that items were matched on underlying or deep structure. Slight differences in surface structure may have signalled different deep structures among matched items, prompting students to give different rationales for their responses (see Paivio & Begg, 1981). For example, items 3 and 4 (given in the section of this paper describing the development of the test) had two slight differences in surface structure which may have influenced the way

students processed the item. First, item 3 had two noun agents ("Mr. and Mrs. Roberts"), whereas item 4 had three ("Sandy, Julia, and the drill coach"). The additional noun agent in item 4 may have made that item more difficult to process (see Schank, 1982).

Second, in item 3, the pronoun to be identified was followed by a pronomial phrase ("her calculator"), whereas in item 4, the pronoun to be identified was followed by an adverbial phrase ("some extras"). The adverbial phrase in item 4 required the student to take an extra step to process the item; namely, determining that the "extras" referred to the "pom poms". Taken together, these differences in surface structure may have made item 4 more complex than item 3. While it seems reasonable that students with specific rules of pronoun usage would not be affected by such differences in grammatical structure, this hypothesis has never been examined empirically and so cannot be ruled out a priori.

Third, a greater number of items may be needed to obtain consistent responses. In the test developed and used here, there were only two matched items per topic of pronoun usage. One could argue that students would have demonstrated greater consistency across more items. The careful matching of the items and the lack of consistent reasons given by students for selecting responses argue against this hypothesis. However, further studies should use more items per topic in the domain to test this hypothesis.

The fourth hypothesis, and the most persuasive, is that students' misconceptions about pronoun usage were not well defined or precise. That is, students may not have had any well-articulated rules upon which

to draw, and thus could not apply any rules consistently. The inconsistency of students' rationales for selecting their responses tends to support this hypothesis. For matched items, students often gave one rationale for selecting the pronoun in one item (such as identifying the gender of the referent) and used a different rationale, a vague one, or no rationale for the other item (such as identifying the number of the referent, or merely saying "It sounds good", or saying "I don't know"). Sometimes students identified the correct referent in one item and indentified the wrong referent in the other matched item. For items so carefully matched in grammatical structure, this behavior suggests strongly that students did not consistently use systematic misconceptions or erroneous rules to answer the test items.

If students do not use consistent strategies for answering test items in pronoun usage, which is probably one of the most well-ordered subject areas of language arts, then analyzing patterns of students' responses to identify errors may not be possible in language arts. What remains to be tested is whether analysis of students' response patterns can be successfully applied in other areas outside of mathematics.

The results of the present set of studies also have implications for other measurement issues. The first relates to the diagnostic strength of item distractors (Roid & Haladyna, 1982) and their use in adaptive testing, where decisions about branching depend on the specific answer a student gives for an item or set of items (Roid, 1969; Swinton, 1984). In such adaptive testing situations, decisions for branching made on the basis of specific responses depend on placing confidence in the student's

response. If students' responses do not correspond to systematic misconceptions, as the data in this paper suggest for language arts, such branching decisions may often be misleading or erroneous.

A second implication is related to assumptions about students' test-taking behavior which apparently underlie certain measurement models and theories. The feasibility and usefulness of answer-until-correct (Wilcox, 1982) and confidence marking models (LeClerq, 1981), for example, seem to assume a systematic and analytic approach to test tasks, where students are able to rule out, or probabilize, their responses on the basis of systematic analysis of both problems and available responses. The results of the present study suggest that such assumptions may be untenable for young students. An analytic approach would imply that students go through a parallel set of steps in answering each item, scanning and categorizing each problem in terms of a consistent set of key features, using a consistent cognitive model. The rationales which students provided here, however, indicated that they did not attend to the same key features in responding to parallel items: stimuli which were salient in one problem were not in the next and thus students did not respond in a uniform fashion. Their responses were not random, but their conceptualization of the problem seemed to vary, perhaps as a function of carelessness, perhaps as a function of an incomplete or inconsistent cognitive model. Further, students seemed not to attend to item distractors to help them formulate their response; i.e., there was no evidence that students arrived at an answer by ruling out certain alternatives.

While these results may raise important questions about the comprehensiveness and usefulness of some new theories applied to younger children, the problem may lie with the mental model underlying the test. One might argue, for example, that students' behavior appeared random because it was evaluated against an inappropriate mental model and/or that the model was at too gross a level of generality. Even though the test domain was very carefully developed, based on curricular and instructional structure and embodying teachers' perceptions of the types and reasons for student errors, such a criticism cannot be overruled. However, given the care exercised in test development and the attention to the available research base, one must question whether it is possible and/or feasible, given the current state of the research, to build classroom tests in a variety of subject areas which reflect appropriate mental models.

The studies reported here investigated the development of a diagnostic test which would provide information not only about students' attainment of particular skills and/or objectives but would also help to identify the sources of their errors and thus provide teachers with concrete guidance designing remedial strategies. The findings lead to pessimism regarding the feasibility of such an approach in routine classroom practice, in terms of the resources required for test development, the level of precision likely to be attained given the current state of the art, and the number of items and student testing time which would be required. On a more specific level, the results are discouraging as to the current feasibility and utility of deriving information beyond traditional right-wrong scoring from student test responses in areas other than mathematics.

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Table 1

Percentage of Students in Study 1 with Each Response Pattern

Matched Pair of Items	Both Correct	Both Incorrect: Same Error	Both Incorrect: Different Error	One Correct, One Incorrect
Non-Relative				
Non-Embedded				
Nominative	90	5	2	2
Objective	85	1	1	13
Embedded				
Nominative	14	27	23	37
Objective	39	6	15	39
Relative				
Non-Embedded				
Nominative	49	6	6	38
Objective	8	35	27	30
Embedded				
Nominative	32	11	16	40
Objective	9	29	27	35
Average over all Measures	41	15	15	29

Note: n = 79

Table 2

Percentage of Students in Study 2 with Each Response Pattern

Matched Pair of Items	Both Correct	Both incorrect: Same Error	Both incorrect: Different Error	One Correct, One Incorrect
Non-Relative				
Non-Embedded				
Nominative	95(15)[a]	0(-)[b]	0(-)	5(0)
Objective	95(10)	0(-)	0(-)	5(0)
Embedded				
Nominative	29(17)	19(50)	0(-)	52(18)
Objective	57(33)	0(-)	5(0)	38(0)
Relative				
Non-Embedded				
Nominative	52(27)	0(-)	10(50)	38(0)
Objective	14(33)	29(33)	10(0)	48(20)
Embedded				
Nominative	67(36)	5(0)	5(0)	24(20)
Objective	29(17)	19(25)	10(50)	43(11)
Average over all Measures	55(24)	9(27)	5(20)	32(9)

Note: n = 21

a: Percentage of the students in this cell who gave the same rationale for choosing both answers.

b: Because no students gave this combination of answers, it was not possible to examine consistency of rationales.

Table 3

Percentage of Students in Study 3 with Each Response Pattern

Matched Pair of Items	Both Correct	Both Incorrect: Same Error	Both Incorrect: Different Error	One Correct, One Incorrect
Non-Relative				
Non-Embedded				
Nominative	100(42)[a]	0(-)[b]	0(-)	0(-)
Objective	88(30)	0(-)	0(-)	12(33)
Embedded				
Nominative	35(56)	27(14)	12(0)	27(57)
Objective	80(30)	4(100)	4(100)	12(0)
Relative				
Non-Embedded				
Nominative	62(53)	8(100)	0(-)	29(28)
Objective	5(100)	43(22)	33(29)	19(75)
Embedded				
Nominative	64(50)	4(0)	4(0)	27(17)
Objective	4(0)	54(54)	33(12)	8(0)
Average over all Measures	55(45)	18(48)	11(28)	17(30)

Note: n = 26

a: Percentage of the students in this cell who gave the same rationale for choosing both answers.

b: Because no students gave this combination of answers, it was not possible to examine consistency of rationales.