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ABSTRACT

This study investigated the effects on the performance of different age group students of: (1) method of task presentation; (2) format or test questionnaire; and (3) the numerical content of the tasks. The sample consisted of 556 students from grades 7, 9 and 12. The tasks, used for assessing reasoning skills, were taken from the Video-Taped Group Test. Experiment one tested the effect of the method of task presentation (video-taped demonstrations versus paper-and-pencil tasks with ilustrations). Experiment two tested the effect of questionnaire format (multiple-choice versus short essay answers) and experiment three tested the effect of the numerical content on the responses of students from different age groups. Analysis of the data indicated that method of task presentation had effect only on young students (grade seven) performance, while numerical content had effect on the majority of the students, in all grades. The only students which were indifferent to numerical content changes were the formal reasoning students. The implication of these findings to science education and cognitive level assessment indicates the importance of concretization in the instructional process of young students and the importance of the mathematical aspects behind a scientific problem. (Author/PN)

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THE EFFECTS OF FORMAL REASONING TASK'S CHARACTERISTICS ON THE RESPONSES OF DIFFERENT AGE GROUP STUDENTS

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The Effects of Formal Reasoning Task's Characteristics on the Responses of Different Age Group Students

Abstract

The study examines the effects of Piagetian-like tasks' characteristics on the performance of these tasks by different age group students. The tasks were taken from a formerly developed and validated test, which measures students' reasoning skills in six cognitive operations: conservation, proportions, control of variables, probability, combinations and correlations. Subjects were 7th, 9th and 12th grade students, enrolled in two urban schools.

Three different 3x2 factorial research design experiments, with three levels of students age and two versions of the test in each experiment, were set up for this study. Experiment 1 tested the effect of the method of task presentation (video-taped demonstrations versus paper-and-pencil tasks with illustrations). Experiment 2 tested the effect of questionnaire format (multiple-choice versus short essay answers) and experiment 3 tested the effect of the numerical content (integer ratio like 1:2, 1:3 versus noninteger ratio like 2:3, 3:5) on different age group students' responses. Analysis of the data indicated that method of task presentation had effect only on young students performance, while numerical content had effect on the majority of the students, in all grades. The only students which were indifferent to numerical content changes were the formal reasoner ones. The implication of these findings to science education in general, and to cognitive level assessment in particular, are discussed.

The Effects of Formal Reasoning Task's Characteristics on the Responses of Different Age Group Students

Introduction

In the last decade, group tests for assessing students cognitive levels took the place of the Piagetian clinical interviews. Some of these tests are just paper-and-pencil tests (Longeot, 1965; Raven, 1973; Renner, 1979), some are based on real demonstrations (Lawson, 1978; Shayer & Wharry, 1974) and others are based on video-taped demonstrations (Staver & Gabel, 1976; Tubin & Capie, 1981; Shemesh & Lazarowitz, 1984). The use of different methods to identify students' reasoning levels may cause the situation of contradictory findings in different studies, and by that reduce the ability of drawing meaningful conclusion from students performance on these tests. Staver (1984) for example, found that format of assessment in Piagetian-like reasoning tasks, but not method of presentation, had effect on college students' level of performance. In another study with 8th grade stuents, Staver (1985) found that the format of the questionnaire had no effect on students' level of performance.

Wollman (1982) while testing the influence of tasks' content on student performance, found out that content can inhibit reasoning if it is too familiar. Studying the same issue, Linn et al (1982) found that familiar content cause students to adopt formal reasoning strategies more easily.

The use of different tests is not the only source for the unclarity of these issues. Another possible source is that in each study different age group students were tested. Working memory and information processing capacity are still developing within the years of childhood to adolescence (Pascual-Leone and Goodman, 1979). Since information processing is a mediating variable between task's characteristics and students' performance, students' age should be considered, while studying this issue.

Thus, the goal of this study was to investigate the effects which method of task presentation, format of test questionnaire and the numerical content of the tasks, may have on the performance of different age group students. While in other studies, students' age was kept constant, in this study the age served as independent variable in order to find out the effect of each of the above mentioned factors separately. No attempt was made, in this study, to find the possible interactional effects of tasks' variables.

Research Design

Sample: The Sample consisted of 556 students from 7th, 9th and 12th grade, which were enrolled in urban schools, located in middle class environment. All students in the same grade level cover a similar curricula which includes one course in mathematics and at least one course of science per year, for every year of the secondary school.

Instruments: The tasks, used in this study for assessing reasoning skills, were taken from the Video-Taped Group Test (VTGT), which was developed for assessing cognitive levels of Israeli secondary school students (Shemesh, 1983). The test is based on 12 video-taped tasks, which were taken, with necessary adaptations, from Lawson's test (1978). In each task, the video-taped demonstration served as prop for raising questions to the observers. The test has an internal reliability of .83 and inter-judge scoring agreement of 91%. Its content and construct validity were reported by Shemesh & Lazarowitz (1984). A schematic presentation of VTGT tasks is displayed in Appendix A.

Scoring: For each correct answer and explanation, students received 2 points; for a wrong answer but a correct explanation - 1 point, zero points for the other two possibilities. Thus each student was eligible to receive a score from 0 to 24 points.

Procedure: As the effect of each independent variable was studied separately, the specific design of each experiment and its results will be presented and discussed separately.

Experiment 1 - Method of Task Presentation:

In this experiment the tasks were presented to subjects in two methods: 1) Video-taped group demonstration (V); 2) written questions with graphic illustrations (W). Examples of two tasks with W mode of presentation are displayed in Appendix B).

The effect of method of task presentation on the level of task performance was analyzed by age and gender. Each age group consisted of two intact classes, which were randomly selected from the appropriate grade level, thus forming a 3 x 2 x 2 research design (7th grade, N = 71; 9th grade, N = 64; 12th grade, N = 40) x (V; W) x (boys and girls).

Mean scores, standard deviations and t-test comparisons of the findings are presented in Table I.

INSERT TABLE I ABOUT HERE

As for a possible interaction effect among age, gender and method of task presentations, students' scores were treated by a three-way analysis of variance. Results are displayed in Table II.

INSERT TABLE II ABOUT HERE

The results of the analysis of variance indicate that age and gender were the main contributors to the variance in students' performance, but method and the interaction between method and age had also significant contribution. There was no interaction between method of presentation and students' gender.

The results of this experiment showed that 7th graders performed significantly higher on the VTGT than on the written version of this test. This effect was not found with 9th and 12th grade students.

Experiment 2 - Format of Questionnaire:

In this experiment the questions which follow each demonstration were of two formats: 1) Multiple choice questions with requirement for essay justification (M); 2) open questions which required short essay answers (E). Examples of M & E formats are displayed in Appendix C. In each grade level, students from 2 classes were randomly assigned to one, out of two formats of questionnaires, thus forming a 3x2x2 research design (7th grade, N = 73; 9th grade, N = 72; 12th grade, N = 56) x (M;E) x (boys and girls). All students, in all grades, watched the same video-taped demonstrations and their questionnaires were followed by the same illustrations. Mean scores, standard deviations and t-test comparisons of the findings are presented in Table III.

INSERT TABLE III ABOUT HERE

Three-way analysis of the variance (grade x gender x format of questionnaire) of students' scores with the two formats of the questionnaire are displayed in Table IV.

INSERT TABLE IV ABOUT HERE

The results showed that format of questionnaire had no effect on students' performance on the VTGT at least in grades 7th, 9th and 12th.

Experiment 3 - Task's Numerical Content:

In this study, the effect of the numerical content of two quantitative tasks from the VTGT (proportions and probability) was studied. For this study a new version of the VTGT was created, in which the numerical values of the variables of two tasks were changed: 1) In the task "Trees and Shadows" the non-integer ratio (3:5) was changed to integer ratio (1:2). 2) In the task "Wooden Squares" the non-integer ratio (2:3) was changed to integer ratio (1:2). The other 10 tasks were identical in the two VTGT's which were administered to the subjects, therefore, only the performance in these tasks was analyzed. This analysis was performed by comparing the percentage of students' correct answers on the different versions of the two tasks, and are presented in Table V.

INSERT TABLE V ABOUT HERE

Findings in Table V showed that the type of ratio (integer/non-integer) between variables had significant effect on students' performance in all grades in the sample. While the non-integer ratio items were treated with the concrete additive approach, even in the 12th grade, the integer ratio items were treated with proportional strategy, by 55%, 80% and 92% of students in grades 7th, 9th and 12th respectively.

Discussion

The results of this study indicate that there is an interaction between subjects' age and their reaction to various characteristics of formal reasoning tasks. While the format of the test questionnaire did not influence students' achievement in any age, the method of tasks' presentation affected performance of young subjects (grade 7th). Finally, the mathematical content of the quantitative tasks influenced students' performance in all ages.

Since the interactions betweem age and response differed by variables, each one will be discussed separately.

1. The impact of the method of tasks' presentation

The results of the experiment in which students' achievement were evaluated in relation to the methods of task presentation showed that the method had effect only on 7th graders who performed significantly higher in the video-test than in the paper-and-pencil test only. These results can be explained by the assumption that the majority of young students (12-13 years old) are in the level of concrete operational thinking and their abstraction ability is still very low. The video method of presentation provided students with the necessary concrete examples and by that helped them overcome lack of abstraction ability. The older students who have a higher ability of abstraction did not need the demonstration. They could understand the nature of the tasks just by reading them.

It should be mentioned that the use of a video method of tasks presentation motivated students in all grades to perform the tasks.

2. The effect of questionnaire format

Analysis of students' answers on the two different format of questionnaires have shown that the multiple-choice format has introduced no bias to the students. Warren (1979) found that it is easier to receive high scores on multiple-choice tests than in open questions' tests. This was not the case in this study, since the fact that students were required to justify their choice has diminished the guessing factor.

3. The effect of task's numerical content

Task's numerical content was found to have an important influence on the strategies which students, of all ages, used while solving proporton and probability problems. When integer ratio was used, most students succeeded to identify the correct solving strategies. When non-integer ratio was used, most students used primitive (additive) strategies. Similar results were found by Hart (1980) who tried to identify hierarchial levels in the development of mathematical concepts. She found that while 1:2:3 ratio problems were introduced, more than 50 percent of the students succeeded in solving the problems, compared to less than 30 percent of success with 2:3:5 ratio problems.

According to Inhelder (1977), from 12 years and up, children can solve probability problems by using combinatorial and proportional operations. Accepting Inehlder's analysis as valid, students' performance on the probability tasks is depedent on their ability to identify the ratio between the target sample and all the sample. In other words, students' failure to perform the probability task results from their inability to identify the functional relationship which exists in the task and not from their misunderstanding of probabilistic concepts. The high percentage of correct responses to the 1:2 probability tasks provide support to the above thesis.

Implication for science education

Although the reasoning tasks used in this study were not in the borders of a specific science subject matter, the results have an implicaton in high school science education:

a) The importance of concretization in the instructional process of young students. This study re-emphasized the need of using concrete demonstrations while introducing concepts and principles in science instruction. Although the need for concretization decreases with students' maturation, still demonstrations may play an important role when students are exposed to new and unfamiliar subjects.

b) The importance of the mathematical aspects behind a scientific problem. It is well accepted that mastery of many science concepts learned in high school required mathematical background (for example mechanics problems in physics; equations in chemistry, or Mendelian genetics in biology). Sometimes the mathematical aspects of a subject matter and not the concepts themselves cause misunderstanding of scientific concepts. While familiar mathematical content such as the 1:2:3 ratio may facilitate the internalizaton of formal strategies of problem solving, unfamiliar mathematical content (3:5:7) could draw students to adopt primitive strategies (as for example the additive approach instead of the proportional one in our experiment). Science concepts have enough inherent difficulties for the inmature learner and we better not confuse students by increasing those difficulties by using unfamiliar mathematical content.

Implications for formal reasoning test construction

While Piagetian clinical methods of assessment (Inhelder & Piaget, 1958) enable a deep study of childrens' modes of reasoning, group tests enable a vast survey of student mastery of different reasoning skills. The use of demonstration is important especially for young students (12-15 years old) who begin the transition from concrete to formal operational reasoning. On the other hand the use of the video-taped demonstrations restricts students' assessment to schools which have video-recorders. Since the performance of reasoning tasks by older students is not affected by the method of tasks presentation, demonstrations can be omitted when students above 15 years old are tested. Maybe it will be worthwhile to develop paper-and-pencil tests, which include more tasks in each operation for these students. These tests should include tasks with different levels of difficulty to increase tests' discriminative power. The analysis of students' answers will enable the teacher or the investigator to better understand the reasoning patterns of his students. From a methodological point of view, it is desirable that researchers who study students' reasoning level will report in details the tasks and methods which were used. This information will make possible the comparison between the results of different studies and by that help clarify the whole issue.

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Table I

Means, Standard Deviations and t-Values
of VTGT Scores, by Method

Grade	Method	N	Mean	SD	t-Values
7th	V	38	6.89	3.06	2.78*
	W	33	4.94	2.66	
9th	V	35	10.80	4.12	0.61
	W	29	10.10	5.11	
12th	V	20	15.65	5.07	0.77
	W	20	16.85	4.71	

V : Video-taped demonstrations.
W : Written questions with illustrations.
* : $p<0.01$

Table II

Three-way analysis of variance of students' scores on the VTGT, by grade, gender and method of task presentation

Source	DF	SS	F	P
Grade	2	2721	90.6	0.0001
Gender	1	288	19.22	0.001
Method	1	29	3.53	0.052
Method x Grade	2	75	5.46	0.001
Method x Gender	1	25	1.72	n.s.

r = 0.58; N = 175

Table III

Means, Standard Deviations and t-Values of VIGT Scores, by Questionnaire Format

Grade	Format	N	Mean	SD	t-Values
7th	M	34	6.85	3.34	0.13
	E	38	6.76	2.42	
9th	M	34	10.20	4.36	0.81
	E	37	9.45	3.57	
12th	M	28	13.39	4.68	0.26
	E	29	13.71	4.51	

M : Multiple choice questions.
E : Essay answers.

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Table V

Percentage of correct answers to different types of proportional and probability items

Item	7th(N=62) %	9th(N=71) %	12th(N=48) %
Proportions (3:5)	5	23	72
Proportions (1:2)	55	80	92
Probability (2:3)	7	30	64
Probability (1:2)	72	85	100

Table IV

Three-way analysis of variance of students' scores on the VTGT, by grade, gender and format of questionnaire

Source	DF	SS	F	P
Grade	2	1703	81.3	0.0001
Gender	1	368	35.2	0.001
Format	1	60	2.45	n.s.
Grade x Gender	2	9	0.45	n.s.
Format x Grade	2	13	0.61	n.s.
Format x Gender	1	4	0.42	n.s.
r = 0.52; N = 200				

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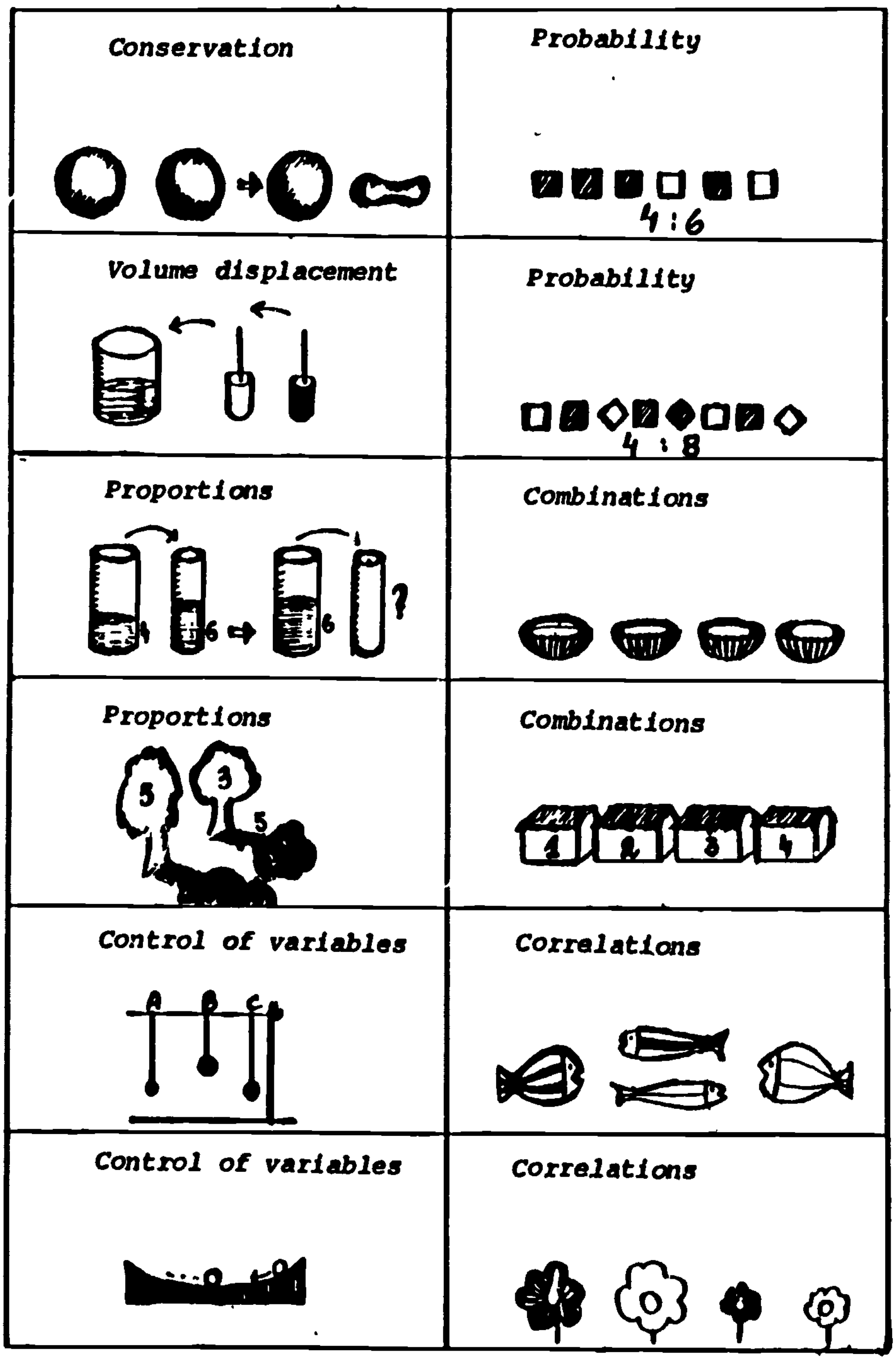
Appendix A

Schematic description of VTGT tasks



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APPENDIX B

Two Examples of written questions with illustrations (W mode of task presentation):

Item 7: I put 4 red squares and 2 yellow squares into a sack.

With closed eyes, I pulled out one square.

What are the chances that this square is red?

Item 9: Suppose you have four different kinds of food (A,B,C and D).

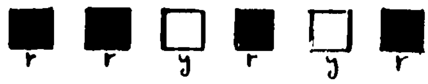
How many different meals can you combine from these foods?

APPENDIX C

Examples of the Multiple-choice (M) and short essay answers (E) formats of questions, which followed the VTGT demonstrations:

M Format

Item 7: Squares



What are the chances of pulling a red square out of the sack?

☐ 1 out of 2　☐ 2 out of 4
☐ 1 out of 4　☐ 2 out of 6
☐ 1 out of 6　☐ 4 out of 6

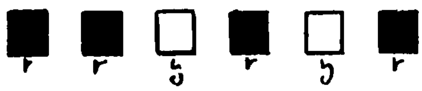
Explain your answer: ______________________

____

____

E Format

Item 7: Squares



What are the chances of pulling a red square out of the sack?

Explain your answer: ______________________

____

____

M Format

Item 12: Flowers

Is there any relation between the colour and the size of the flowers in this sample?

15　3　4　9

☐ No, most of the big flowers are white.
☐ Yes, most of the big flowers are white.
☐ No, there are flowers of all kinds.
☐ Yes, there are flowers of all kinds.

Explain your answer: ______________________

____

____

E Format

The same stem, but without the four alternatives.