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ABSTRACT

The constructs of concrete and formal operational reasoning were examined in 459 15-year-old secondary school students (234 males and 225 females) in Singapore. Log linear models were used to explore the relationships between Piagetian level of reasoning, the level of intelligence, gender, and type of home-speaking environment among these adolescents. Instruments used were the pendulum task of Shayer's Science Reasoning Task and Raven's Advanced Progressive Matrices. The formal operational level is associated with a higher level of intelligence and English-speaking homes, and has gender differences in favor of the males. It is possible that students from Chinese-speaking homes may not have comprehended the questions fully. More research is needed to address this problem. Three tables present study findings and analysis results. (SLD)

A STUDY OF THE CONSTRUCTS OF CONCRETE AND FORMAL OPERATIONAL REASONING IN ADOLESCENTS[1]

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ABSTRACT

This study examines the constructs of concrete and formal operational reasoning in fifteen-year-old students in Singapore. It uses log-linear models to explore the relationships between the Piagetian level of reasoning, the level of intelligence, gender and type of home-speaking environment of these adolescents. It was found that the Piagetian level of reasoning depended on the level of intelligence, gender and type of home language-speaking environment of the subjects. The formal operational level was associated with a higher level of intelligence, English-speaking homes and has gender differences in favour of the males.

[1] Paper presented at the 1993 NCME Annual Meeting, Atlanta, 13-15 April 1993.

A STUDY OF THE CONSTRUCTS OF CONCRETE AND FORMAL OPERATIONAL REASONING IN ADOLESCENTS

Objective

This study examines the constructs of concrete and formal operational reasoning in fifteen-year-old students in Singapore. It explores the relationships between the Piagetian level of reasoning, the level of intelligence, gender and type of home-speaking environment of these adolescents. To establish the relationships, log-linear models are used to fit multivariable models to the data.

Perspective

According to Inhelder and Piaget (1958, 1964), formal thinking emerges and consolidates between the ages of 12 to 15. Formal reasoning is considered to be an abstract, as opposed to concrete, means of thinking. Piaget showed that at the concrete operational stage (which lasts from about age 7 to age 12), a child is able to perform mental operations such as identity and reversibility with respect to real and concrete objects. At the formal operational stage, the adolescent is able to conduct "mental experiments" in which hypothesized possibilities are logically analyzed and deductions are made prior to acting. Thus formal operational adolescents employ a systematic rather than a trial-and-error approach to problem solving.

Above average students have been selected for this study as empirically, a large percentage of average adolescents and adults do not function at the formal operational level (Blasi & Hoeffel, 1974). Shayer And Wylam (1978) found through studies on their tests that one should select students from the top 20% to 40% of the cohort to ensure that there would be students in the range of late

concrete to late formal operational. In accordance with Shayer and Wylam, students in this study were selected from the top 40% of the cohort so that there was a greater likelihood of a proportion of the students being formal operational.

Data Source

The data for this study came from a dissertation data set collected in Singapore by the author for a study that considered the relationships between intelligence and Piagetian tests (Lim, 1987). The study was conducted on 459 Secondary 3 students in 15 schools. The schools with above average students had been selected by a stratified random sampling design. In this sample of students there were 234 males and 225 females.

The instruments used this study were the pendulum task of Shayer's Science Reasoning Task (Shayer, 1979) and Advanced Progressive Matrices (Raven, 1962). The pendulum problem is one of the tasks which Inhelder and Piaget (1958) used to examine the stages of concrete and formal operational thoughts in adolescents. A group test on the pendulum task, constructed by Shayer (1979) was used for the study. After the pendulum task was scored, the performance of the student was classified as stage 2 (concrete operational level), stage 2/3 (transitional stage to formal level), stage 3 (formal operational level) and stage 4 (advanced formal operational).

The Advanced Progressive Matrices assesses the mental ability of adolescents and adults with above-average intellectual ability by means of non-verbal abstract analogical reasoning. According to their scores on this test, the students were classified into the average intelligence group, the above-average intelligence group and the higher intelligence group.

Analyses and Results

The multivariable data set was classified in the form of a multidimensional contingency table to be analyzed simultaneously by log-linear models. The 4 qualitative variables are variable A (with its 3 levels of intelligence: A1, A2 and A3), variable B (with its 4 stages of Piagetian level of performance on the pendulum task: B1, B2, B3 and B4), variable C, gender (C1, male and C2, female) and variable D (with its 2 types of language speaking environment at home: D1, English speaking and D2, Chinese speaking). Variables A and B are both ordinal variables. The subjects were cross classified on the variables as shown in Table 1.

Insert Table 1 about here

Although Table 1 was not especially sparse, it contained a number of random zeros and low frequencies. Consequently the Pseudo-Bayes method (with independence priors) was used to adjust the frequencies in the table so as to do away with the random zeros. The adjusted frequencies were then analyzed by a log-linear method, initially considering all the four variables as independent variables so as to examine mutual relationships among them. The ECTA program was used to examine a number of heirachical models to find the best fitting log-linear model.

Insert Table 2 about here

The nine heirachical models and their associated G^2 statistics are summarized in Table 2. The

best fitting parsimonious model for the data was Model 5 (Independence + AxB + BxD + BxC + AxD) as the G^2 was 12.35 with 21 degrees of freedom. This model accounted for 86% fit of the data. Model 5 implied that the Piagetian level of reasoning of a subject was significantly associated with the intelligence level, gender and type of language-speaking environment. In addition, there was a significant relationship between intelligence level and the type of home language-speaking environment. There was no significant relationship between the intelligence level and the gender of the subject.

Insert Table 3 about here

Since the focus of interest of this study was on the Piagetian level of reasoning of the subject, the data were then reanalysed using the asymmetric model to study the effects of variables A (level of intelligence), C (gender) and D (type of home speaking environment) on the dependent variable B (Piagetian level). The results of this analysis are summarized in Table 3. The best fitting parsimonious model was Model 4, with a G^2 of 8.88 and 21 degrees of freedom. This model, accounting for 88% fit of the data, showed that the Piagetian level of reasoning of a subject was likely to depend on the level of intelligence, the type of language-speaking environment and the gender of the subject.

The tau parameters of the significant interactions indicated that higher intelligence tended to be associated with formal and advanced formal operational levels and average intelligence with concrete operational and the transitional levels. More boys were likely to be formal operational than girls. The more advanced formal operational students tended to be from English speaking homes and more concrete operational students, from Chinese-speaking homes.

Discussion and educational importance of study

This paper has examined log-linear models to aid in the understanding of the contingency tables formed from the four qualitative variables in the study. It was found that students who were formal operational tended to have a higher level of intelligence, whereas students who were concrete operational tended to have a lower level of intelligence. This finding is supported by correlational and factor-analytic studies that found positive relationships between the scores of the WISC or Stanford-Binet and the scores on the Piagetian tasks (Carroll, Kohlberg and DeVries, 1984; Dodwell, 1962; Dudek, Lester, Goldberg and Dyer, 1969; Humphreys and Parsons, 1979). Carroll et al. and Humphreys and Parsons found a general factor underlying both the intelligence tests and Piagetian tasks, indicating that intelligence is a broad attribute. Constructors of intelligence tests could consider adding Piagetian tasks to their tests.

The analysis also revealed gender differences in the pendulum task in favour of the boys. Meehan (1984) carried out a meta-analysis of 53 studies on formal reasoning and showed that there were gender differences in favour of the males, with 1% to 5% of the variance being explained by gender. As for the Advanced Progressive Matrices, no significant gender differences were found. This is because the matrices were constructed to "guard" gainst gender bias (Jensen, 1980).

Students from English-speaking home environments appeared to have a higher level of formal reasoning. A possible explanation for this result could be that students who come from a Chinese-speaking home environment may not have been able to comprehend fully the questions asked. This finding highlights a basic problem in Singapore, that students who do not speak much English at home tend to have a lower proficiency in English. This lack of proficiency has affected their performance in school, as instruction in all subjects and testing are both carried out in English. More research need to be carried out on this problem in Singapore as we need to identify the causes of the problem and work out strategies to solve the problem.

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Table 1 Observed Frequencies by intelligence level (A), Piagetian Level (B), gender (C) and language speaking environment (D).

		C1				C2				
		B1	B2	B3	B4		B1	B2	B3	B4
D1	A1	1	12	12	5	A1	8	14	5	3
	A2	0	9	19	2	A2	5	18	12	4
	A3	0	13	29	10	A3	3	10	15	15

		C1				C2				
		B1	B2	B3	B4		B1	B2	B3	B4
D2	A1	10	18	13	0	A1	19	28	11	1
	A2	6	23	18	3	A2	10	11	13	0
	A3	1	8	20	2	A3	1	7	9	2

Table 2 Symmetric models fitted to the adjusted cross tabulated data

	Model	G^2	df	Gain G^2	Gain df	Cumulative % gain in G^2
M1	A B C D	94.63	40	-	-	-
M2	+ AXB	57.94	34	36.69**	6	41%
M3	+ BXD	35.97	32	21.97**	2	62%
M4	+ BXC	21.76	28	14.21**	4	77%
M5	+ AXD	13.48	26	8.28**	2	86%
M6	+ AXC	12.52	24	0.96	2	87%
M7	+ AXCXD	8.88	21	3.64	3	91%
M8	+ BXCXD	6.02	18	3.33	3	96%
M9	Saturated	0	0	7.64	18	100%

** $p < .01$

Table 3 Fitting of asymmetric models to the adjusted cross tabulated data

	Model	G^2	df	Gain G^2	Gain df	Cumulative % gain in G^2
M1	B, AXCXD	73.27	33	-	-	-
M2	+ AXB	36.57	27	36.70**	6	50%
M3	+ BXD	21.23	24	15.34**	3	71%
M4	+ BXC	8.88	21	12.35**	3	88%
M5	+ BXCXD	6.18	18	2.70	3	92%
M6	+ BXAXC	4.48	12	1.70	6	94%
M7	+ BXAXD	2.78	6	1.70	6	96%

** $p < .01$