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Preliminary Study of Reasoning Ability of Cerebral Palsied Children on Columbia Mental Maturity Scale (CMMS)

——Cross-Sectional Study on Development of Non-Handicapped Children——

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The purpose of this study is to conduct a cross-sectional examination of developmental change in reasoning ability of non-handicapped children focusing on a solution strategy, as a preliminary study to clarify developmental characteristics in reasoning ability of cerebral palsied children.

In the first study, the responses of 540 subjects to the Columbia Mental Maturity Scale Japanese edition were studied by factor analysis. In the second study, the responses of 720 subjects were analyzed by item performance curve.

From the first study, it was revealed that the children dominantly used oddity strategy till the age of five, the pairing strategy became dominant from the age of six, and the children began to be able to use both strategies flexibly after the age of eight.

In the second study, drops in the rate of correct response were observed at the ages of upper 6, lower 7, and lower 8 in 6 items of the 92 items of the CMMS. The study suggested that children showed response behavior which was not explainable from the perspective of oddity-pairing strategy.

Longitudinal study and qualitative researches such as analysis of verbal response on nonhandicapped children are planned. Studies of cerebral palsied children by the same research designed to clarify the developmental characteristics of reasoning ability of cerebral palsied children are also planned.

Key Words: Reasoning Ability Solution Strategy Cross-Sectional Study
Columbia Mental Maturity Scale (CMMS)

Introduction

Reasoning is a function or process of thinking to reach a conclusion from a premise. Previous research on thinking or conceptualization of cerebral palsied children (Cotton, 1941; Dolphin, 1951; Ernhardt, 1965; Dague and

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Garelli, 1969) has revealed the following characteristics of thinking of cerebral palsied children. (1) The children use on excessively larger number of categories in classifying objects in comparison with normal children. (2) The criteria of classification which are produced by paying attention to easily perceived attributes like color, shape, etc., or by relying on unimportant peripheral attributes were observed. The erratic criteria, which were produced by their own experience or by imagination, were also observed. (3) The children showed difficulty in transferring from one criterion to the other: i.e. from color to shape. (4) These characteristics were observed among the cerebral palsied children within normal IQ range.

The upper mentioned studies did not have developmental perspectives. Matsubara (1968) and Young (1977) conducted studies from developmental perspectives. Matsubara compared scores of the cerebral palsied children with their non-handicapped counter-parts using the Abstract Ability Test developed by Irwin & Hammill (1964). Young (1977) indicated the need to study cognitive development of cerebral palsied children from the Piagetian point of view. These studies, however, failed to examine qualitative changes in development of the thinking process as suggested by Piaget (1937; 1950). Cerebral palsied children often have both motor impairments and associated problems, such as perceptual difficulties, which may affect the thinking of children at a certain stage of development. Quantitative comparison of test performances between cerebral palsied children and non-handicapped children is not enough. Comparison of solution strategy between the two groups is necessary to study reasoning as a function or process of thinking by which a conclusion is reached from a premise.

The purpose of this study is a cross-sectional examination of the developmental changes in reasoning ability of non-handicapped children using the Columbia Mental Maturity Scale (CMMS, Japanese Edition) from the point of solution strategy as a preliminary study to clarify developmental characteristics of the reasoning ability of cerebral palsied children.

The reasons for using the CMMS are as follws: General reasoning ability measured by the CMMS is observed to be closely related to abilities of classification and categorical thinking. The CMMS is designed to evaluate children of age levels from 3 years 0 months to 9 years 5 months, during which time children develop most of their intellectual function in thinking strategy. The scale is a powered test and requires only a "Yes" or "No" sign to indicate the answer. The scale is free from motor and speech impairments. Different types of items (Dague and Garelli, 1969; Reuter and Mintz, 1970; Kaufman, 1978) are included in the CMMS to measure the reasoning abilities of children at different developmental stages. It is understood that the children may use different solution strategies to solve problems.

This research focuses on solution strategies of children responding to items of the CMMS and aims to explicate developmental change in general reasoning ability in children. The research is composed of two studies. One presents factor analysis and the other the analysis of the item performance curve.

Study One : Developmental Change of Solution Strategy by Factor Analysis

Purpose of Study

The purpose of this study is to reveal the change of solution strategy by factor analysis.

Method

Subjects. The sample population for this study is composed of 540 Japanese children (270 males and 270 females) aged 5 years 0 months to 9 years 5 months. This sample population is equivalent to those sampled for standardization of Test Levels E to H of the CMMS Japanese

Table 1. **Profile of Subjects and Range of Items Used by Factor Analysis**

Test Level	Administered Age Level	Number of Subjects	Range of Items Used for this Study*
Level E	5 yrs. 0 ms. to 5 yrs. 11 ms.	120	21 to 74
Level F	6 yrs. 0 ms. to 6 yrs. 11 ms.	120	31 to 84
Level G	7 yrs. 0 ms. to 7 yrs. 11 ms.	120	35 to 89
Level H	8 yrs. 0 ms. to 9 yrs. 5 ms.	120	38 to 92

* Subjects, test levels, age levels, and range of items are those of the CMMS Japanese Edition.

edition (ibid.). Table one shows the profile of subjects and range of items used by factor analysis.

Administration. The standard administration procedure for the CMMS was followed. The range of items used in this study were those of the standardized norm.

Method of analysis. A factor analysis of interitem correlation was conducted by principal component analysis with iterative estimation of communality and varimax rotation at each test level. Processing was made by PA2, SPSS (Nie, N.H. *et al.*, 1975).

Results

Factors to be interpreted were selected by

Table 2. **Results of Factor Analysis (Test Level E)**

1st Factor		2nd Factor		3rd Factor		4th Factor	
Item No.	Factor Loadings	Item No.	Factor Loadings	Item No.	Factor Loadings	Item No.	Factor Loadings
48	.714	22	.748	68	.646	27	.711
37	.650	26	.745	65	.539	30	.618
34	.547	30	.628	53	.527	38	.517
50	.535			67	.423	36	.417
47	.493			63	.409		
				74	.403		

Table 3. **Results of Factor Analysis (Test Level F)**

1st Factor		2nd Factor		3rd Factor	
Item No.	Factor Loadings	Item No.	Factor Loadings	Item No.	Factor Loadings
68	.630	76	.770	37	.702
81	.566	53	.515	39	.568
75	.509	77	.497	36	.501
83	.455	80	.408		
80	.403				

Table 4. **Results of Factor Analysis (Test Level G)**

1st Factor		2nd Factor		3rd Factor	
Item No.	Factor Loadings	Item No.	Factor Loadings	Item No.	Factor Loadings
83	.691	77	.668	63	.667
75	.567	76	.585	70	.452
78	.549	52	.581	46	.406
81	.441	67	.416		
65	.418				

Table 5. **Results of Factor Analysis (Test Level H)**

1st Factor		2nd Factor		3rd Factor	
Item No.	Factor Loadings	Item No.	Factor Loadings	Item No.	Factor Loadings
71	.779	64	.778	80	.682
51	.662	82	.673	81	.641
40	.509	77	.592	76	.598
79	.492	66	.550		

the sklee test of variance of factors. The first to fourth factors were selected at test level E. The first to third were selected at test levels F to H. Tables 2 to 5 show items with factor loadings larger than .400.

Results of interpretation

In interpreting factors, the following four principles were introduced. 1) Interpretations were made according to three explanators: Oddity-Pairing, Level I-Level II, and Constructed Principle. (See Appendix.) 2) An interpretation which was common among authors was adopted. 3) Interpretaion of a factor was made by following characteristics of an item with larger factor loading to those of an item with smaller factor loadings. 4) An item which was observed predominantly at a certain factor and was not observed at other factors was considered to be one which exclusively represented the characteristics of the factor. Results of interpretation are summarized on Table 6.

Test level E. At the first factor, items which appeared with larger factor loadings were all oddity items and symbolic identification of elements were observed to be necessary to solve problems. The first factor, therefore, was interpreted as the factor of Oddity by Symbolic Identification. The second factor was interpreted as Oddity by Visuo-Perceptual Judgment due to visuo-perceptual stimuli, which is characterized by items 26 and 30. Although item 22 was originally designed as an item of pairing: two trees and two ducks, this item was interpreted as oddity. It was observed that the visual impression of a picture of a girl with candy overwhelmed impressions of two pairings. The third factor was interpreted as the factor of Pairing by Visuo-Perceptual Judgment due to items 65, 53, 67, and 74. Although item 68 was originally defined as oddity at the point of standardization, the task of this item is also solved by pairing and was included in this category of interpretation. It was observed that children solved the task of pairing by visual stimuli: a pair of 4 vertically lined dots and 4 horizontally lined dots, and a pair of 4 dots placed at the corners of a rectangle and 4 dots placed at the corners of a diamond instead of

Table 6. **Results of Interpretation of Factors**

Test Level	Chronological Age of Administration	1st Factor	2nd Factor	3rd Factor	4th Factor
E	5 yrs. 0 ms. to 5 yrs. 11 ms	Oddity by Symbolic Identification	Oddity by Visuo-Perceptual Judgment	Pairing by Visuo-Perceptual Judgment	Unable to Interpret
Item Used for Interpretation of Factor		48, 37, 34, 50 47	**22**, 26, 30	**68**, 65, 53, 67 **63**, **74**	27, 30, 38, 36
F	6 yrs. 0 ms. to 6 yrs. 11 ms.	Pairing by Visuo-Perceptual Judgment	Pairing by Concept Operation	Oddity by Symbolic Identification	
Item Used for Interpretation of Factor		**68**, 81, 75, 83 80	76, 53, 77, 80	37, 39, 36	
G	7 yrs. 0 ms. to 7 yrs. 11 ms.	Pairing by Visuo-Perceptual Judgment	Pairing by Concept Operation	Unable to Interpret	
Item Used for Interpretation of Factor		83, 75, **78**, 81 65	77, 76, 52, 67	63, 70, 46	
H	8 yrs. 0 ms. to 9 yrs. 5 ms.	Oddity by Concept Operation of Spatial Relation and Number	Pairing with Inflexible Concept Operation	Pairing by Concept Operation of Function and Number	
Item Used for Interpretation of Factor		71, 51, 40, 79	**64**, **82**, 77, **66**	80, 81, 76	

An item presented by bold-faced numbers is the one of which original definition of either pairing or oddity at the point of Japanese standadization does not coincide with interpretaion by factor analysis.

using oddity rule in number concept, 5 dots and 4 dots. The fourth factor could not be interpreted.

Test level F. The first factor was interpreted as the factor of Pairing by Visuo-Perceptual Judgment. The interpretation of item 68 coincides with the one at the third factor of Test Level E. The second factor was interpreted as the factor of Pairing by Concept Operation due to concept operation of the use of things in solving tasks. All three items included in the third factor were oddity items. Symbolic identification as the first factor of Test Level E was needed to solve tasks. This factor was interpreted as the factor of Oddity by Symbolic Identification.

Test level G. The first factor of Test Level G was interpreted as the factor of Pairing by Visuo-Perceptual Judgment as observed in items 83, 75, 81, and 65. It was estimated that responses were influenced by visual impressions of drawings. Although item 78 was originally defined as an oddity, this item can be solved by pairing strategy as well and the item was also interpreted as on item in Pairing by Visuo-Perceptual Judgment. The second factor of this level was also interpreted in the same way as the second factor of Level F and named Pairing by Concept Operation. The third factor was uninterpretable.

Test level H. The first factor of Test Level H was interpreted as a factor of Oddity by Concept Operation of Spatial Relation and Number, as known from items in which the task was to select an abstract figure from the others. From pairing items, the second factor was interpreted as the factor of pairing. It was observed that children used relatively rigid response behavior, such as Within-Figure pairing at which partial portions of a single figure were isolated and were matched as a pair within the figure. Therefore this factor was interpreted as the factor of Pairing with Inflexible Concept Operation. The third factor was interpreted as the factor of Pairing by Concept Operation of Function and Number due to tasks which require judgments of quantity concept or functions of things.

Discussion

Interpretation of factors over four test levels revealed the following findings. In test levels of lower age, the Oddity strategy is more dominant than the pairing strategy. Visuo-perceptual judgment is also dominant at lower age test levels. Items which were different from the developer's expected solution strategy were observed.

Both Kaufman (ibid.) and Hiskey (ibid.) suspected children's response behavior to be different from the developers' intention. The results of the factor analysis coincide with Kaufman and Hiskey. The same items appeared at different axes at different test levels in the factor analysis. Children at different age levels interpreted these items differently from the developers' intention. Bold-faced numbers on Table 6 indicate such items.

It is considered from the interpretation of factors that the solution strategy of children changes at different age levels. It is observed that oddity strategy is predominantly used by five-year olds. Although use of pairing strategy at the visuoperceptual level is expected at earlier age levels, it is from age level six that the use of pairing by concept operation becomes clear. At the age of eight, solution strategy begins to differentiate. Rather than to apply a single solution strategy exclusively to any situation, children start flexible use of multiple solution strategies while selecting the most appropriate one for a certain situation. However, this flexible use is not an established one and children may stray in selecting an appropriate strategy. Children may interpret situations excessively and coercively apply a solution strategy as observed in items 64, 82, and 66 of factor 2 at Level H.

Study Two : Developmental Change Attributable to Age Increase by Analysis of Item Performance Curve

Purpose of Study

The purpose of this study is to clarify the developmental change in reasoning ability of children based on responses to the CMMS items. The study examines the change in proportion of right answers in each item over age by an item performance curve which designates the change in the proportion of choice element over the increase in chronological age. The study attempts to reveal the changing tendency attributable to increase in age.

Method

Subjects. The sample population of this study is composed of 720 Japanese children (360 males and 360 females) aged 3 years and 0 months to 9 years and 5 months, the sample data used for the standardization of the CMMS Japanese edition (ibid.). See Table 7.

Administration. The administration procedure suggested in the manual of the Japanese edition was followed. Ranges of items used in this study were wider than item ranges described in the manual, as shown in Table 7. This wider range was set in order to clarify the changing tendency in proportion of choices attributable to increase in age.

Table 7. **Profile of Subjects and Range of Items Used for Analysis of Item Performance Curve***

Age Level of Subjects	Number of Subjects	Range of Items Used for this Study
3 yrs. 0 ms. to 3 yrs. 5 ms.	60	1 to 55
3 yrs. 6 ms. to 3 yrs. 11 ms.	60	1 to 55
4 yrs. 0 ms. to 4 yrs. 5 ms.	60	1 to 66
4 yrs. 6 ms. to 4 yrs. 11 ms.	60	7 to 70
5 yrs. 0 ms. to 5 yrs. 5 ms.	60	9 to 74
5 yrs. 6 ms. to 5 yrs. 11 ms.	60	13 to 74
6 yrs. 0 ms. to 6 yrs. 5 ms.	60	25 to 89
6 yrs. 6 ms. to 6 yrs. 11 ms.	60	25 to 89
7 yrs. 0 ms. to 7 yrs. 5 ms.	60	25 to 92
7 yrs. 6 ms. to 7 yrs. 11 ms.	60	25 to 92
8 yrs. 0 ms. to 8 yrs. 5 ms.	60	33 to 92
8 yrs. 6 ms. to 8 yrs. 11 ms.	60	33 to 92
9 yrs. 0 ms. to 9 yrs. 5 ms.	60	33 to 92

* Subjects used for this study are equivalent to those used for the standardization of the CMMS Japanese edition. Age levels and range of items are those originally used to develop the norm of the CMMS Japanese edition.

Method of analysis. Percentages of choices in each item were plotted against age as criterion. Item performance curves, thus drawn, by each item were eye-inspected by the authors.

Results

Items were classified into six regular types and an irregular type according to changing pattern in item performance curves against age as criterion. An item for which the item performance curve showed an increasing tendency in response attributable to age increase was considered to be a regular type. If the item performance curve of an item changed from an increasing trend to a decreasing trend and the drop from the highest spot of the curve showed more than a 10% decline at the following higher age level, the item was defined as an irregular type.

Regular types. Figure 1 shows the typical patterns of item performance curve of correct responses classified as regular types. They are: 1) Increase Types (Simple and Stepwise), 2) Top Flat Types (High Level and Low Level), and 3) Minute Increase Types (High Level and Low Level). Numbers at the right side of the graphs are the number of items classified into the types. A total of eighty five items among ninety two were classified as one of the regular types.

Irregular type. Seven items for which the curves showed a marked drop in the middle were classified as irregular type and further examined together with incorrect choices. Items were examined if a marked drop in correct responses corresponded with the increase of incorrect choices over chance levels (100% divided by the number of choices) at the same age level. Items: 41, 54, 78, 79, 80, and 82, were thus defined as irregular type. Item 59 was discarded from interpretation despite its irregular pattern because none of the incorrect choices on this item exceeded chance level. Figures 2 to 7 show the patterns of item performance curve of the six irregular type items.

Table 8 shows age levels at which drops of correct responses at age levels of upper 6,

Types of Curve		Graphs	Number of Items Classified
1) Increase Type	Simple		5
	Stepwise		19
2) Top Flat Type	High Level		33
	Low Level		7
3) Minute Increase Type	High Level		13
	Low Level		8
Total			85 items.

Fig. 1. **Types of Item Performance Curve and Number of Items Classified**

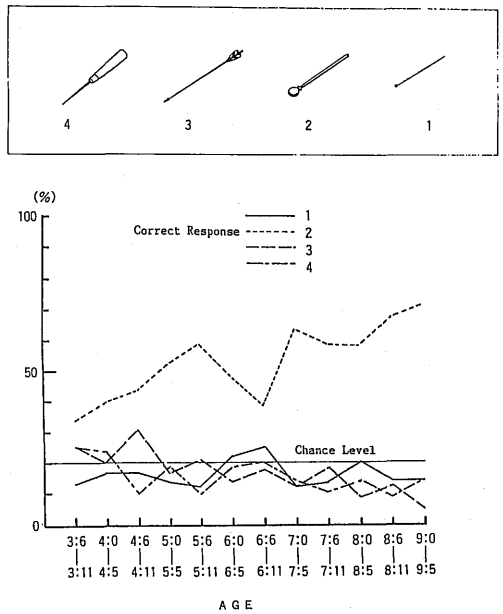


Fig. 2. **Item Performance Curve of Item Number 41**

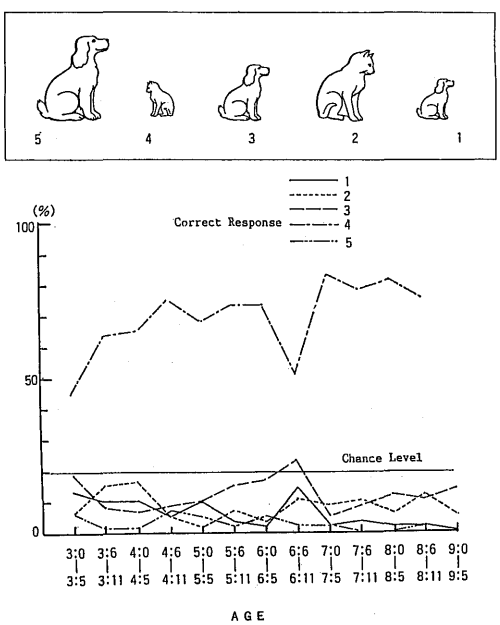


Fig. 3. **Item Performance Curve of Item Number 54**

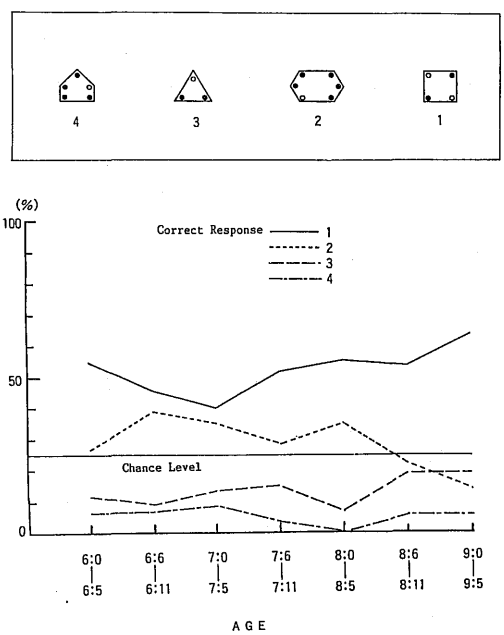
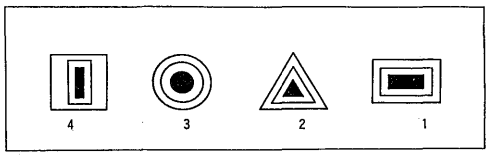


Fig. 4. **Item Performance Curve of Item Number 78**



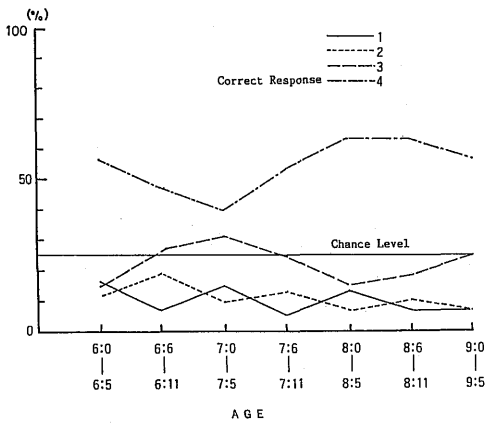
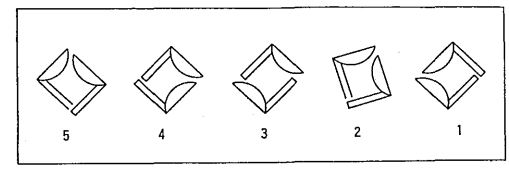


Fig. 5. **Item Performance Curve of Item Number 79**



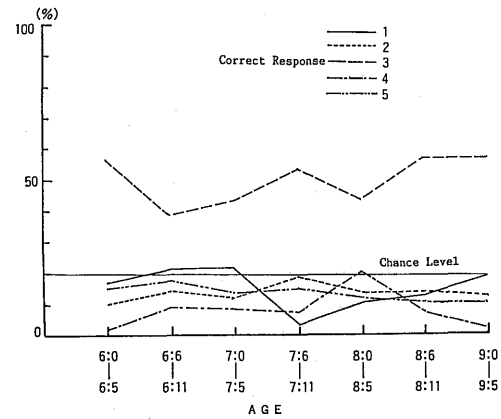
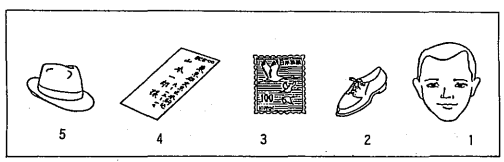


Fig. 6. **Item Performance Curve of Item Number 80**



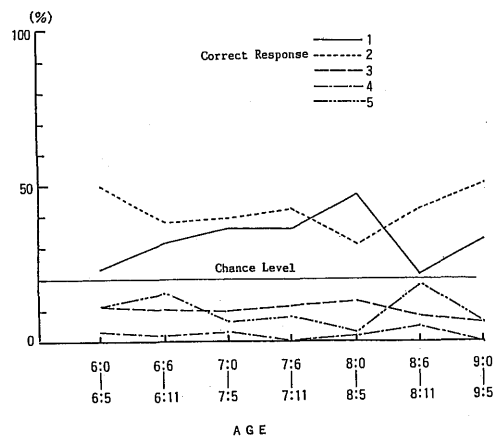


Fig. 7. **Item Performance Curve of Item Number 82**

lower 7, and upper 8 are observed. It is recognized that items classified as irregular type were all Level II items. Five out of six irregular items were oddity type items.

Discussion

Piaget (1937, 1950 quoted in Gruen, 1985) viewed the development of intelligence as a staged process explained by four major periods. Drops of correct responses are observed at upper six and lower seven age levels on irregular items of the CMMS. This age range approximately coincides with the transitional age ranges of Piaget's preoperational period to concrete-operational period.

Dague and Garelli (1979) cross-sectionally reviewed responses on the CMMS, and reported a drop of correct responses around the ages of eight and nine, which are defined as a confusion period. Drops of correct responses at the lower eight age level which approximately coincides with Dague & Garelli's confusion period were observed in two of the six irregular type items of the Japanese edition. This result

Table 8. **Drops of Correct Responses of Irregular Type Items.**

Item Number	Age levels at which drops of correct responses are observed	Item Type
41	6 ys. 6 ms. to 6 ys. 11 ms.	O-II
54	6 ys. 6 ms. to 6 ys. 11 ms.	O-II
78	7 ys. 0 ms. to 7 ys. 5 ms.	O-II
79	7 ys. 0 ms. to 7 ys. 5 ms.	O-II
80	8 ys. 0 ms. to 8 ys. 5 ms.	P-II
82	6 ys. 6 ms. to 6 ys. 11 ms. / 8 ys. 0 ms. to 8 ys. 5 ms.	O-II

is close to Dague and Garelli's report of more confusion on Generalization type items.

A drop in the number of correct responses on the irregular items at age levels of upper six, lower seven, and lower eight are not considered to be attributable to skewed sampling toward lower groups. Concerning the six irregular items, performances of the group which passed the item and the group which failed the item were compared at the age levels where the drops were observed. There was no evidence that the drops were systematically produced by the differences in performance by the two groups.

The analysis of item performance curves on incorrect choices of six irregular items revealed the phenomenon that the percentage of response at a certain age level of a certain incorrect choice increases as the percentage of correct choice decreases. For example, there is a decrease of correct responses on item 80 at age level 8 years and 0 months to 8 years and 5 months. Choice one, which is an incorrect response, uniquely increased beyond chance level at the same age level but other incorrect choices remained the same. This suggests a change of solution strategies by age. In the case of items on the CMMS Japanese edition, it is suggested that upper 6, lower 7, and lower 8 are age levels where changes in solution strategy appear in the drop of correct responses.

Conclusions

Outcomes from Factor Analysis

The factor analysis revealed that children develop their solution strategy with the increase of their age. They start from a monotonous use of simple solution strategy, then shift to a more complicated solution strategy. Finally the children obtain flexibility in selecting the most appropriate solution strategy for a certain situation. They start to use a simple strategy for a simple situation and a complex one for a complex situation.

The solution strategy of children changes from visuo-perceptual judgment to conceptual operation, and from oddity to pairing with the increase of age. Up to age five the oddity strategy is superior. The pairing strategy is estimated to be established at age six. The solution strategy by conceptual operation attains superiority after age eight. The age at which flexibility in selecting solution strategy is

attained is estimated to be after age eight.

Outcomes from Item Performance Curve

Decreases of correct responses were observed in upper 6 and lower 7 age levels on 5 items among the irregular type items. The decreases were also observed in the lower 8 age level of 2 items. These drops correspond with the increase of incorrect responses as if the decrease in correct responses is substituted by an increase in incorrect responses.

It is estimated, from the responses of children on the same item, that there are changes in solution strategy by chronological age. As far as can be ascertained from the 6 items of the CMMS, the age levels at which solution strategy changes are estimated to be upper 6, lower 7, and lower 8. The upper 6 and lower 7 levels correspond with Piaget's late preoperational stage and early concrete-operational stage. The lower 8 level also corresponds with the confusion period of Dague and Garelli. It is suggested that a change in solution strategy may be caused by an explanator different from the Oddity-Pairing which appears at these age levels.

These six items, which do not show an increase of correct responses attributable to age increase, may need further review from the point of view of psychometry. However they are considered to be meaningful as items to appraise qualitative changes in the reasoning ability of children.

Further Research

This study is based on quantitative data which are analyzed cross-sectionally. Perspectives of interpretation of this research are three kinds of explanators: Oddity-Pairing, Level I -Level II, and constructed principle. These perspectives were compared with choice of answer, which was the quantitative data at different age levels.

In this study, the reasoning ability and its development were explicated indirectly through quantitative data in terms of solution strategy. For precise analysis of the reasoning process, it is recommended to compare constructed principle with children's verbal explanation qualitatively.

The authors also recognize the importance of longitudinal study to follow the developmental changes of both reasoning ability and process. The authors plan studies of cerebral palsied children with the same research design to clarify the developmental characteristics of reasoning abilty in cerebral palsied children.

Appendix

Oddity-Pairing, Level I-Level II

Reuter and Mintz (1970) suggested two rules to be applied in the solution of items of the CMMS. The "oddity rule" is to select an element of an item which does not belong to a class with common characteristics. The "pairing rule" is to select an element of an item which is left from the other pairs. Fujita (1981) suggested classification from two aspects, item types and level of conceptualization, would clarify the classification of the items. The items are classified into four categories: Oddity-I, Oddity-II, Pairing-I, and Pairing-II. Following the symbolization introduced by Dague and Garelli (ibid.), the categories are explained as follows.

An item which is described by A-A-X (An item which is composed of three elements), A-A-A-X (An item which is composed of four elements), and A-A-A-A-X (An item which is composed of five elements) is defined as Oddity I (O-I). In this category, elements other than the right choice element are identical as visual stimulus. An item which is described by A_1-A_2-A_3-X, A_1-A_2-A_3-A_4-X is defined as Oddity II (O-II). In this category, elements other than the right choice element are conceptually identical but perceptually may differ. An item which is described as (A-A)(B-B)-X is

defined as Pairing I (P-I). Here, the parenthesized abbreviation (A-A) means a pair of two elements with the identical visual stimulus. The (B-B) means another pair of two elements with the identical visual stimulus. In this category, two elements A-A are grouped as a pair and another two different elements are grouped as another pair, then an element left without its pair is a correct choice. An item which is described as (A-A') (B-B')-X is defined as Pairing II (P-II). Here, the abbreviations A and A' (B and B') are conceptually identical but perceptually different elements.

Constructed Principle

The constructed principle is a frame of reference constructed by researchers on the solution strategy of each item. For example, three dogs facing right, one cat facing right, and one cat facing left are drawn in item 41 (Figure 2.). Constructed principle of item 41 is a concept of direction: animals facing toward the right.

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