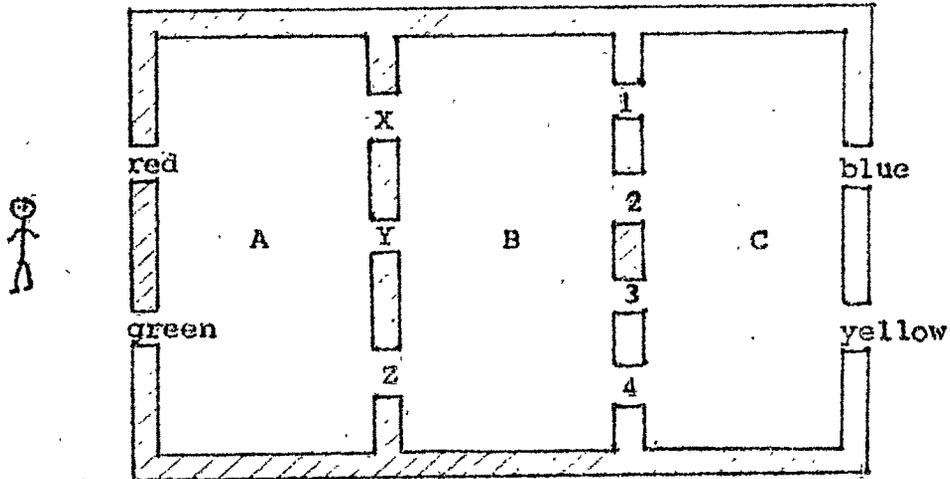


## APPENDIX B

Tasks for assessing the reasoning patterns and the criteria for assessment

Task I: Fun House Puzzle\* (combinatorial reasoning)



The above given plan of a three room house is given to the interviewee. The interviewer then enters into a dialogue with the interviewee explaining that the figure shows the diagram of a house having three rooms A, B and C. To enter the room A there are two doors coloured red and green. One can enter through any one of the doors. From the first to the second room, there are three doors marked X, Y and Z. From the second to the third room, there are four doors marked 1, 2, 3, and 4. From the third room to go out there are two doors coloured blue and yellow. If one has to pass through the three rooms, one has to pass through four doors. For example, pointing at the figure outside the house, the interviewer shows that one has to pass through the red door, A door, door numbered 1 and the blue door to pass through the three rooms and go out.

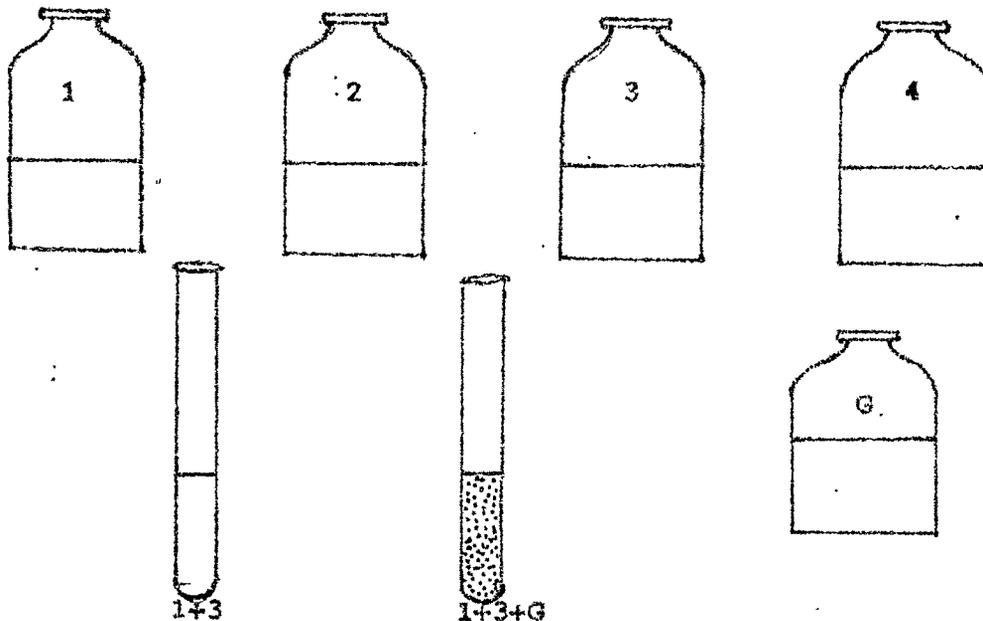
Then the interviewer asks the interviewee to show all the other possible ways of passing through the three rooms. The interviewee is supplied with a paper and pencil to write all the possible ways i.e., all possible four door paths as given in the example.

\* Adapted from Walker et. al., (1979) p.212.

Criteria for assessment

- II A - The subject who simply attempts combinations of a single set of doors from among the four sets viz., red and green; X, Y and Z; 1, 2, 3 and 4; and blue and yellow. That is, one who finds more than one path but less than five.
- II B - This substage is characterized by one who goes about solving the problem with the basic combinations and with the addition of  $n \times n$  and  $n \times n \times n$  combinations. That is, finding out more than six paths and less than 25.
- III A - This substage is characterized by  $n \times n$ ,  $n \times n \times n$ , and  $n \times n \times n \times n$  combinations. That is, finding out more than twenty six paths without proper explanation of the combinatorial system.
- III B - This substage is characterized by all possible combinations i.e., finding out all the forty eight paths in a systematic way and explaining how it was found.

Task II: Coloured Chemicals<sup>®</sup> (combinatorial reasoning)



<sup>®</sup> Refer Inhelder and Piaget, (1958) Pp.107-108

The interviewee is given four similar bottles containing colourless liquids which are perceptually identical. They are numbered: 1 (dilute sulphuric acid); 2 (water); 3 (oxygenated water); and 4 (thiosulphate solution). Another bottle with a colourless liquid with a dropper is added to the above four. This is labelled G. The interviewee is shown a test tube containing a colourless liquid. The interviewer tells that the liquid is taken from one of the four bottles or combinations of two or more from the four bottles. The interviewer then adds a few drops of the liquid G to the test tube. The colour of the liquid changes to yellow. The interviewee is then asked to do various experiments to produce the yellow colour. They are supplied with test tubes (washed and cleaned). Detailed observations are made on the combinations tried out by the interviewee. If the interviewee stops after a couple of trials, he is persuaded to try all possible combinations.

Criteria for assessment\*\*

- II A - The subject who simply attempts combinations of a single liquid with G or all four with G, without any other combinations, is in substage II A. Any hypothesis formed will be quantitative (too much water or too little water) dealing with only serial ordering or correspondence. If the colour is achieved, it will be fortuitous and the colour will be attributed to a single liquid rather than a combination.
- II B - This substage is characterised by the same basic reactions, with the addition of some  $n \times n$  combinations with G or  $n \times n \times n$  combinations with G. At this substage the subject will not continue to experiment without reasonable prompting.
- III A - The two innovations that appear at this substage are the introduction of a systematic method in the use of  $n \times n$  combinations and an understanding that the colour is the resultant of a combination rather than coming from one of the liquids. A subject at this substage, when producing a colour producing combination, does not stop there, but goes on. He tests other combinations.
- III B - The difference between the substage II B and the earlier one is only of degree. In this substage the combinations and proofs are organised more in a systematic fashion with the experiment organised from the start with the intent to find the proof.

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\*\* Refer Renner et. al. (1976)

**Task III:                    Photosynthesis Puzzle<sup>2</sup> (controlling of variables)**

The interviewer supplies the interviewee data regarding five experiments conducted under different conditions. The different conditions and the results of the experiment are given in the following table.

Container	Plant	Part of the plant	Light colour	Temp. °C	CO <sub>2</sub> remaining
1	Tulasi	leaf	blue	10	200
2	Balsam	leaf	purple	23	50
3	Tulasi	root	red	18	300
4	Balsam	stem	red	23	400
5	Tulasi	leaf	blue	23	150

Initial amount of carbon dioxide in all the jars is 250 units and all jars are kept in these conditions for two days.

The interviewer describes the experiments by telling that the jars are kept under different conditions for two days. He then asks the interviewee to explain the five experiments in his own language. This is to ensure that the interviewee has understood the conduct of the experiment. Taking cues from the talks of the interviewee and using the same words, the interviewer asks the following question. On the basis of the data given in the table, which two jars or containers will you compare to find out the amount of carbon dioxide absorbed per day at two different temperatures. It is implied in the question that the other conditions have to be the same. But, this clue is not made obvious to the interviewee.

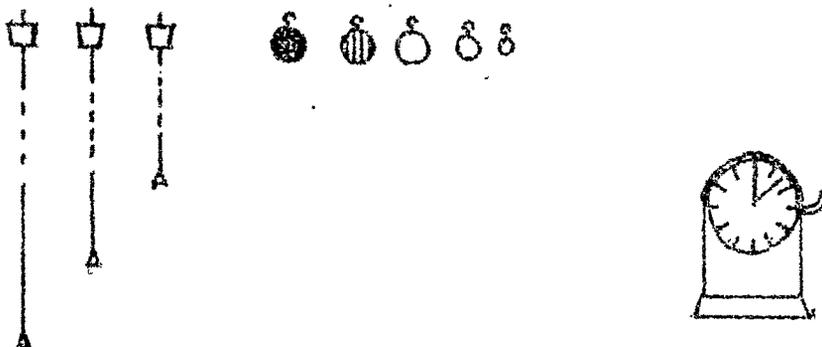
**Criteria for assessment**

- II A - The subject who simply answers by comparing any two jars kept at two different temperatures or the same temperature with improper explanations.
- II B - This substage is characterised by the comparison of two jars kept at two different temperatures and controlling any one or two of the other three sets of variables viz., plant, parts of the plant and colour of light. The controlling is expressed through proper explanations.
- III A - This substage is characterised by the subject who compares two jars kept at two different temperatures and controlling three sets of variables, but not supporting it with proper explanation or who changes his line of argument on probing further.

<sup>2</sup> Adapted from Wright (1979)

III B - A subject who compares two jars at different temperatures by controlling all the other variables and giving valid explanations for the same.

Task IV: Pendulum<sup>#</sup> (controlling of variables)



The interviewer gives three threads of different length to the interviewee, a stand to fix the thread, and a set of bobs. The bobs are of different sizes and weights. Among the five bobs, three are large (their volume is the same, but the material is different and so the weights are different), one is lead, the second brass, and the third an aluminium bob. A set of two more aluminium bobs are given to the interviewee. They are of varying volume. The three threads have a hook each tied at one end and the bobs can be hung on these hooks. The interviewer then asks the interviewee to make different pendulums using one thread and a bob at a time, and make them swing each time. He is supplied with a stop watch. The interviewee is asked to answer the following question after conducting various experiments. Which among the factors viz., length of the string, mass of the bob, volume of the bob, and the height at which the bob is released affect the period of motion of the pendulum? In other words, what factor makes the bob go up and down slow or fast?

The activities carried out by the interviewee is noted in detail by the interviewer.

Criteria for assessment

II A - The subject who simply cannot control any of the variables. The fairly obvious variables are: 1) the weight of the bob, 2) the length of the string, 3) the height of the dropping point, and 4) the

<sup>#</sup> Refer Inhelder and Piaget, (1958) Pp.68-69

magnitude of push given to the bob.

- II B - This substage is characterised by controlling one or two among the obvious variables except the relevant variable, i.e., the length of the string.
- III A - This substage is characterised by controlling the variables one by one keeping others constant, but, fails to explain his action.
- III B - This substage is characterised by controlling the variables systematically and giving a proper explanation for his actions.

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Task V: Hockey Player Puzzle<sup>2</sup> (combinatorial reasoning)



The above figure is shown to the interviewee and he is supplied with coloured paper cuttings of sets of jerseys, shorts/skirts, stockings and boots. That is, jerseys of four colours viz., Orange, Purple, Green and Yellow; shorts/skirts of three colours viz., Red, Lemon and Violet; stockings of two colours viz., Cockey and Ivory; and boots of two colours viz., Black and White. The interviewer then places one set of jersey, shorts/skirts, stockings and boots on the figure and explains to the interviewee how the set forms one way of putting on or wearing the playing gear. Then the interviewer

<sup>2</sup> Developed by the investigator.

asks the interviewee to try and find the different possible ways in which the player can wear the sets of gear given to them.

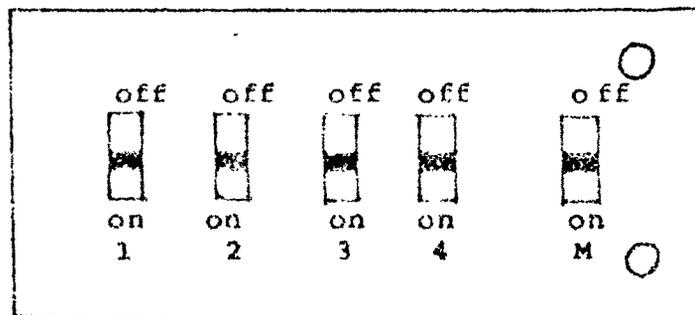
The interviewer then makes detailed observations regarding the way the interviewee goes about solving the puzzle.

#### Criteria of assessment

- II A - The subject who attempts only a single set of gear from among the different sets possible. That is, one who finds more than two ways of wearing the gear and less than five ways.
- II B - This substage is characterised by the same basic combination with an addition of  $n \times n$  and  $n \times n \times n$  combinations. That is, finding more than six different ways of wearing the gear and less than twenty five ways.
- III A - This substage is characterised by  $n \times n$  combinations,  $n \times n \times n$ , and  $n \times n \times n \times n$  combinations. That is, finding out more than twenty five ways of wearing the gear without proper explanation of the combinatorial system.
- III B - This substage is characterised by all possible combinations. That is, finding out all forty eight possible ways of wearing the gear and explaining it logically.

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Task VI: Electrical Switching System\* (combinatorial reasoning)



\* Developed by the investigator.

This switching system consists of five switches marked 1, 2, 3, 4 and M. The switches are connected to a dry cell and then to a light emitting diode (LED). The switches are connected in such a way that the combination of switches '1', '3' and 'M' in the 'on' position, the cell and the LED comes in series and the LED emits light. The switch '2' is not connected to the circuit at all. Switch '4' is connected in such a way that, when it is in the 'on' position the circuit to the LED is broken. Therefore, under two combinations of the switches in the 'on' position the LED gives out light. They are: 1) '1', '3' and 'M', and 2) '1', '2', '3' and 'M'.

The interviewer asks the interviewee to try all possible combinations to light the LED. The interviewee is specifically asked to try all possible combinations, even if they could make the LED give out light once.

#### Criteria of assessment

- II A - The subject who simply attempts combinations of a single switch in the 'on' position with 'M' or all four switches 'on' with 'M'. A subject in this substage will not try any other possible combination.
- II B - This substage is characterised by the same basic combinations as given in II A with the addition of  $n \times n$  combinations. That is, more than five combinations but less than ten.
- III A - This substage is characterised by  $n \times n$  and  $n \times n \times n$  combinations, and an understanding that the light is the result of a combination of switches in the 'on' position and not from any one of the switches. A subject at this substage, when finding a light producing combination, does not stop there, but goes on to test other combinations. The subject may not be in a position to give full explanation of the combinatorial system.
- III B - This substage is characterised by the subject who goes about finding the combinations and proofs in a more organised manner. The subject starts with the intention of finding the proof.

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Pots	Type of soil	Manure	Mugs of water/day	Light Condition	Growth of plant
1	Sandy	X	1	shade	14
2	Sandy	Y	3	sun	10
3	Clayey	Z	2	shade	8
4	Mixed	Z	3	sun	12
5	Sandy	X	2	shade	16

The student is given detailed information regarding experiments conducted to find the rate of growth of bean plants. He is told that five mud pots are taken of equal size and are filled with sandy, clayey and mixed soil as given in the table. Three different types of manure are added to the pots as given in the table. Also, the student is supplied with details regarding the conditions under which the pots are kept for a period of two weeks. At each stage of narrating the problem to the interviewee, he is asked to repeat the experimental conditions. This is done to ensure that the interviewee has perceived the problem as the interviewer wants him to.

The interviewee is then asked the following question. By comparing which pots can one study the effect of watering on the growth rate of the plants?

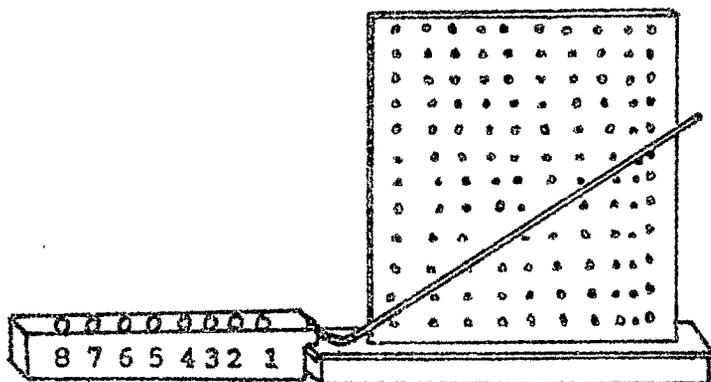
Criteria of assessment

- II. A - The subject who simply compares any two pots kept at two different conditions without caring to control even a single set of variables.
- II. B - This substage is characterised by the comparison of two pots to which different amounts of water has been added per day, but not controlling other sets of variables, viz., type of soil, manure and the light condition.
- III. A - This substage is characterised by the subject who compares pots kept under different light conditions by controlling all other sets of variables with improper explanations.
- III. B - The subject who compares the pots to which different amounts of water is added per day, and controlling all other variables. Also, the subject is in a position to offer proper explanation for his comparison.

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<sup>@@</sup> Adapted from Menon (1985).

Task VIII: Falling Bodies on an Inclined Plane<sup>®</sup> (controlling of variables)



The experimental apparatus consists of a plane adjustable to various angles of incline. A ball can be rolled down the plane; it bounces when it hits a springboard at the base. The problem is to find the relationship between height of the point from which the ball is released and the length of its bound. To study the relationship the interviewee is given steel balls of three different sizes. Since the material with which the ball is made remains the same their weight also changes because of the difference in the volume.

The inclined plane can be raised or lowered by moving the peg on which it rests to different holes in the board. These also serve as an index for measuring height. Balls of varying sizes are released at different heights on this plane, hit a board at the bottom, bound in parabolic curves, and come to rest in one of the compartments (numbered 1 to 8). These are the interviewee's index to the length of the bound.

Criteria of assessment

II A- The fairly obvious variables are; size of the bob, mass of the bob, height from which the bob is rolled along the inclined plane and the distance from the lowest point of the inclined plane. This substage is characterized by the subject who does not control any of these variables.

II B- This substage is characterized by controlling one or

<sup>®</sup> Refer Inhelder and Piaget (1958) Pp.80-81.

two among the obvious variables except the relevant variable i.e., height of the point from which the bob is released.

III A - This substage is characterised by controlling all the obvious variables including the relevant one, but, in an un-systematic fashion and giving improper explanations.

III B- This substage is characterised by controlling the variables one by one in a systematic manner and giving the right explanations.

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