

THE RELEVANCE TO THE THEORY OF INTELLIGENCE
TESTING OF THE STUDY OF ERRORS IN THINKING

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CHAPTER I

A great many widely differing actions are commonly described as manifesting intelligence or lack of it. To some, on the other hand, this description is generally considered inappropriate: we do not talk of intelligent sneezing or of unintelligent digestion of food. That there is no widely agreed convention to mark the borderline is unimportant for the immediate purposes of this discussion. It would be irrelevant to debate here what Piaget calls, in the same connection, "les questions de frontières" ¹. We are concerned now only with the recognition that when an action is described as intelligent this contrast is implied.

It may, however, be implied only in a remote way, as something basic but overlaid. More prominent than the contrast between "intelligent" and "non-intelligent" may be that between "intelligent" and "unintelligent"; and since any action that can be called "unintelligent" must be one that can be called "intelligent" in the first sense (that is, as contrasted with non-intelligent) there is here a certain risk of confusion. "Intelligent" in the first sense refers to the similarity which enables us to construct a rough scale of differences running from "intelligent" in the second sense to "unintelligent". It is as if we lacked the word "weight" and had only the word "heavy" - or "heaviness" - to refer to the similarity which enables us to arrange

1. Jean Piaget: *La Psychologie de l'Intelligence*, p. 16. (Paris; Armand Colin, 1947). In the section from which this quotation is taken Piaget gives an account of the opinions of a number of psychologists on the question of where the line should be drawn.

objects in serial order according to possession of this property.

Lack of the word "weight" might be no very serious disadvantage. But in the case of intelligence matters are greatly complicated by a further distinction which must be made. To make the further distinction easier to discuss I propose to try to resolve the first ambiguity in "intelligent" by using the word "intelligential" - clumsy as it admittedly is - to take the place of "intelligent" in the first sense: that is, to oppose "non-intelligent" and refer to any action which is of the kind that may be intelligently or unintelligently performed.

In the rest of this discussion we shall be talking only of intelligential actions. We must now go on to consider what is being said when an intelligential action is described as "intelligent".¹

We may - and commonly do - apply the name "intelligent actions" to (a) any specific actions for which we wish to make the positive claim that they have been performed in an intelligent manner; and (b) all actions which are of kinds that we judge to give us a sound basis for estimating the intelligence of the performer. (Both senses may of course be present together.) In other words, any given intelligential action may be said to be intelligent - or unintelligent, as the case may be -

1. When we judge an action or a person "intelligent" the judgment of course presupposes some criterion of intelligence; but it would be irrelevant at this point to discuss the choice of criteria since the distinction with which we are here concerned is one which does not depend on the nature of the criteria although their existence is presupposed by it.

with respect both to the manner or "mode"¹ of its performance, and to its "status" as an index of the intelligence of the person who performs it.

At this point the reader may feel inclined to protest at once that any action which is performed intelligently must indicate that the person performing it is intelligent. But consider the following circumstance. In the Terman-Merrill Test, Form L, there occurs at year 10 the "word-naming" test. The child is told: "I want to see how many different words you can name in a minute." Now some children adopt a system in answering. They go round the room naming every object they see. Or they name all the animals they can think of, then all the birds and so on. These are methods likely to yield a considerable number of words quickly, and an answer guided by one of them may be judged more intelligent than one where no system at all is employed. Further, such a judgment can be made independently of knowledge of the person who has given the answer. This, then, is to say that the action is intelligent in mode. But what of the "status" of the attempt to say as many words as possible in a minute? Is it an intelligent action, in the sense we have in mind when we say: "That's

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1. The evidence available for making judgments of mode will vary with the nature of the activity and the particular performance of it. The manner in which an action is performed may sometimes be largely covert, so that only the final result is available for scrutiny. Again, final results themselves vary in the extent to which they reveal the manner in which they were reached. These questions will be raised again in later chapters.

an intelligent sort of thing for an eight-year-old to be able to do"? I do not propose to attempt to answer this status question here. My point is that it is not the same question as the question about mode. To decide that an action is intelligent in mode is not to decide that it is intelligent in status - that it is an intelligent sort of thing for an X-year-old to be able to do. The first decision leaves the second one still to be made.

The question of how the second one is to be made is one with which later parts of this thesis will be concerned. Meanwhile, I would emphasise that we do in fact very commonly make status decisions whereby we judge some intelligently performed actions to be more significant as indices of intelligence than others; that these decisions always have some regard to the age of the performer; and, most important of all, that we commonly take it for granted that our status decisions are of general validity. We say: "That's an intelligent thing for an X-year-old to be able to do" - not "for this X-year-old to be able to do." In fact, the attempt to assess intelligence must be a futile undertaking unless we are justified in assuming that at least some status decisions of quite general validity can be made.

The idea that it may be possible to arrange people in serial order according to possession of some property called "intelligence"

has a long history. Burt¹ traces it back ultimately to Plato's analysis of the soul and from there follows it by way of Aristotle and the mediaeval schoolmen to the faculty psychologists, indicating at the same time the main contributions from biology and physiology to the subsequent growth of the idea. He goes on to say, however, that all the earlier writers on the subject were interested primarily in "the working of the mind as such, that is to say, in problems of general psychology" and that it was not until the time of Galton that attempts were made to "apply scientific methods to the problems of individual psychology." This stressing of the contrast between "general" and "individual" has the rather unfortunate effect of seeming to suggest that it is possible to study the properties of "mind" without studying the properties of minds. It is true that for Galton interest in the differences between minds became primary, whereas previously interest in the similarities had tended to be dominant; but his work was a new departure not so much because of a new awareness of differences in intelligence as of a determination actually to arrange people in order according to these differences, and so to begin mental measuring. It is true, however, that as a result of his work and that of his successors the notion of differences in intelligence has become almost as widely familiar as that of differences in temperature, whereas before his day only the most gross of the differences were commonly recognised,²

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1. Sir Cyril Burt: The evidence for the concept of intelligence: Brit. J. Educ. Psychol., 1955, 25, 158 - 177.
 2. See L.S. Penrose: The Biology of Mental Defect, Chap. I (London: Sidgwick and Jackson, 1949) for a short historical account of attitudes to mental defect.

whatever may have been the perception of great thinkers on the subject.

Galton's views about the nature of the differences are therefore of some consequence, and it is particularly important that he placed as much emphasis as he did on their hereditary nature. In the preface to the second edition of "Hereditary Genius" he writes:

"At the time when the book was written, the human mind was popularly thought... to be capable of almost any achievement, if compelled to exert itself by a will that had a power of initiation. Even those who had more philosophical habits of thought were far from looking on the mental faculties of each individual as being limited with as much strictness as those of his body, still less was the idea of the hereditary transmission of ability clearly apprehended."¹

Galton does not here say how strict he considers the limitation of the "bodily faculties" to be, but the tenor of his subsequent argument implies that he must regard it as very strict indeed. He is careful however to explain his use of the term "ability". It involves "qualities of intellect and disposition":

"I do not mean capacity without zeal, nor zeal without capacity, nor even a combination of both of them without an adequate power of doing a great deal of very laborious work. But I mean a nature which, when left to itself, will, urged by an inherent stimulus, climb the path that leads to eminence and has strength to reach the summit..."²

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1. F. Galton: Hereditary Genius: 2nd ed. (London: Macmillan, 1892).
 2. Ibid. p. 33.

The former idea of the importance of "the will that had a power of initiation" is thus retained in Galton's own theory, but the will itself is regarded as hereditary, as a part of "natural ability". On the other hand the distinction between intelligence and attainment is already clearly implied, for where there is capacity without zeal there will presumably be intelligence without corresponding attainment.

When Binet began the construction of his famous intelligence test scale it was this distinction that he was primarily trying to make. His problem was to find some way of deciding which children should be sent to special schools, and whenever this is seen as a really perplexing problem the desirability of distinguishing between intelligence and attainment has been in some sense recognised. Without this recognition no need would have been felt for intelligence tests.

Yet it is evident from Binet's writings that he found it very difficult to hold intelligence and attainment effectively apart. Thus at one point¹ we find him claiming that when a school is well run and suitable tests of attainment are used there is no better means of telling whether a child is intelligent than by considering in relation to one another his age and his class in school, due allowance having been made for any irregularity of attendance. He goes on:

"This amounts to judging intelligence by the amount of instruction.

1. A. Binet and Th. Simon: *Mentally Defective Children*, p. 39.
(Translated by W. B. Drummond. London: Edward Arnold, 1914.)

Theoretically such a method is open to plenty of meticulous objections of which the most important is that we are confounding intelligence and memory. To this we shall reply that the stage of instruction reached is not the result of memory alone. It presupposes also some degree of application, some facility of comprehension, quite a collection of diverse aptitudes."

But earlier in the same book he has said:

"The end which we have constantly set before ourselves has been to bring to light the intellectual capacity of the child, taken by itself, as distinct from what the child actually knows."¹

And again, later:

"Although arithmetical ability depends upon special aptitude and a child may be quite intelligent though backward in arithmetic..."²

These quotations show Binet acknowledging two important truths, but having some difficulty in reconciling them so as to form one principle to guide his work of test construction. Thus we find him maintaining that we can best judge a child's intelligence by considering the whole sum of his scholastic attainments because they presuppose "a collection of diverse aptitudes"; yet arguing, on the other hand, that some of these attainments are not such good indices of intelligence as others and that "intellectual capacity, taken by itself" can somehow be ascertained.

1. Ibid: p. 28.

2. Ibid: p. 58.

So far as I have been able to discover, Binet never does bring together the two parts of this dual recognition: that a very great many human activities manifest intelligence in the sense that they may be performed more or less intelligently, and yet that certain sorts of activity are of central significance in the estimation of the intelligence of the person. The two notions are not incompatible: their reconciliation merely involves the distinction between "mode" and "status" that was made in the first section of this paper. But unless this distinction is explicitly made there is a very great risk that they will seem to be at war and that like Binet the test constructor will be pulled to and fro between them. How can he make a case for the inclusion in his tests of some kinds of activity rather than others? If they all "manifest intelligence" the obvious course must be to sample them quite randomly. And yet he knows very well that some kinds of task have a stronger claim than others to be represented: that a child may be quite intelligent though backward in this or that. Galton saw this very clearly at the beginning for he speaks of sinking shafts at critical points and of the problem of how to ascertain the best points for the purpose.¹ The trouble is that this has since proved to be no easy problem to solve.

Binet himself failed to solve it, in the sense that he provided no consistent theoretical justification for his choice of points.

1. F. Galton: Remarks on an article by Cattell. *Mind*, 1890, 15, 380-381.

Instead he resorted to what Piaget has called "une sorte de probabilisme psychologique": a sampling of tasks that was as wide as it could be in the time available for testing and yet that was not random since it was guided continually by his own sense of fitness. His sampling was remarkably successful: unfortunately so perhaps, since its very success may have discouraged the sort of further inquiry that would have been most valuable. But this is no fault of Binet's. His own ultimate aim was to come to understand "la nature même de la pensée" and he would never have rested content with the success of his tests, which he produced to serve an immediate practical purpose and for which he made the most modest and cautious of claims.

After his death a succession of immediate practical purposes occasioned the production of a whole series of tests based on a whole series of samplings that were not random and yet not guided by articulate theory. The question of how to choose the critical points and justify the choice was very frequently avoided; and this avoidance was indeed encouraged and applauded - directly or indirectly - by a number of writers.

An interesting example of indirect encouragement comes from the writings of Gilbert Ryle who argues in "The Concept of Mind" that to regard "theorising" as the essential activity of the intelligent mind is a mistake, and proposes to reveal it as a mistake by showing that

"theorising is one practice amongst others and is itself intelligently or stupidly conducted."¹ The last phrase makes it very evident that his argument rests on the confusion of mode and status, for the fact that theorising can be performed in an unintelligent manner is no argument against regarding it as the essential activity of the intelligent mind. The issue here is not, of course, whether Ryle is correct in rejecting theorising as the mind's essential activity. The point is that his argument, if sound, would make it impossible to regard any sort of activity as more important in the estimation of intelligence than any other sort, since, whatever sort was suggested, it would be true that it could be performed in an intelligent or unintelligent way.

An example of direct encouragement is to be found in Alice Heim's recent book "The Appraisal of Intelligence". She devotes a considerable part of her book to the question of test validation, and she expresses approval of Binet's test construction procedure on the grounds that:

"Binet was concerned to find some exact, external criterion with which to compare his test findings. As is well known, he observed and made use of the fact of mental development. Having noted that a normal child of six, for instance, can do things which a normal child

1. G. Ryle: *Concept of Mind*, p. 26. (London: Hutchinson's University Library, 1949.)

of five cannot achieve, and that the six-year-old tends to fail on tasks which the normal seven-year-old can manage, he took 'success at age X' as his criterion."¹

I would be very far from wishing to object to approval of Binet's emphasis on the fact of mental development. But to imply, as Heim does, that this by itself provides an adequate validation criterion is to imply that every power that develops with age is equally important as an index of intelligence, and this Binet himself certainly did not believe. Nor, indeed, does Heim, for though she pays enthusiastic tribute to Binet's recognition that "intelligence manifests itself in a multitude of ways"² she goes on later in the book to imply that not even all "cognitive matters" are to be regarded as "matters of intelligence". This occurs in the course of her discussion of test reliability, at the point where she is considering the problem of possible intrinsic variability in the subjects tested. She says:

"The evidence suggests that intrinsic variability is less in cognitive matters generally, and least in matters of intelligence specifically."³

But how are these "matters of intelligence" to be distinguished? This is obviously the question that must be faced. It might be thought that every definition of intelligence would be an attempt to answer it; but when one studies the many definitions of intelligence that

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1. A. Heim: *The Appraisal of Intelligence*. pp. 24-25. (London: Methuen, 1954.)
 2. *Ibid.* p. 22.
 3. *Ibid.* p. 82.

have been proposed it becomes evident that some of them concern themselves primarily with mode (as does Heim's own tentatively offered one, which perhaps explains why in parts of her book she seems so to overlook the vexed question of status). That is, intelligence is sometimes described not as a capacity to undertake certain sorts of activity but as a general tendency to act in a certain manner whatever the sort of activity.

It is interesting to discover, then, that if one considers statements that refer primarily to mode one finds much agreement among writers of great diversity. Here are a few instances:

Galton, speaking of Cambridge wranglers, says that they are distinguished by the fact that they "find their way at once to the root of the difficulty" and with a few clean, apposite, powerful strokes, succeed in proving they can overthrow it"

Coleridge, in one of the essays in "The Friend", tells us that if we choose a "close reasoner" as our guide to "the summit and absolute principle" of a subject he "will ... take us the shortest way, will save us many a wearisome and perilous wandering ..."

Heim's own suggestion is that "intelligent activity consists in grasping the essentials in a given situation and responding appropriately to them."

And Whitehead exemplifies the quality he describes when he says: "Style is the direct attainment of a foreseen end, simply and without waste."

The end may be of many different kinds, but the style of an elegant solution to a mathematical problem is essentially at one with the style of the best writing, painting or music, which is another way of saying that in all these activities intelligence may manifest itself.

And yet this realisation, important as it is, does not help us to decide what to put in an intelligence test. It has indeed been made to serve as a refuge from the need for theoretical justification of the decisions made, though it cannot offer this escape with anything like convincing plausibility. The argument that it does not much matter what we test since it is the mode of doing that is important cannot be used to support present testing practice because mode is precisely what tests at present pay no regard to except in so far as mode is revealed by final result (which in the kinds of question commonly used and in our present state of knowledge is very little) and perhaps in so far as credit is given for speed. There can be no doubt that there is some connection between speed and style; and yet the person whose manner of doing shows the greatest style or intelligence may be the quickest to reach a solution or he may not; for he may spend his time deliberating and planning and looking for the neatest and most satisfying way to proceed. What we need to know is not so much how long some one takes to reach an answer as how his time is spent.

The desirability of knowing this would probably be acknowledged by most test constructors and users but it has generally been

considered obvious that the difficulties in the way of any attempt to estimate success except in terms of time taken and response made (in the sense of solution finally offered) are overwhelmingly great. In spite of this a few writers have been critical of the practice of studying only overt responses. Luchins, for instance, in the course of discussion of the "Einstellung" effect,¹ argues that apparently identical responses may result from very different thought processes and that it may be quite unsafe to make inferences from the former to the latter; B. Othanel Smith, discussing the use of attainment tests, objects to the gross and superficial study of behaviour on which their construction usually rests. He goes on to express the belief that a more thorough study would reveal that "underlying events are distinguishable in terms of manifestations now slurred over in our gross analysis."² His hope is that searching preliminary studies would ultimately enable us to construct questions in such a way as to obtain even from the final answer alone much more information about the subjects whole response than we are at present able to do.

Smith does not commit himself to any detailed proposals for the conduct of these studies. Though he attacks the practice of studying only final overt responses he is anxious to refute in advance any accusation that he is advocating a return to what he describes as the "barren methods" of introspective psychology. And at the end of his book he tells us that so far as he can see there are two directions

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1. A. S. Luchins: The Einstellung-effect as a test of rigidity. J. Consult. Psych., 1951, 15, 89-94.
 2. B. Othanel Smith: Logical Aspects of Educational Measurement, p.123. (New York: Columbia University Press, 1938).

in which mental measurement may advance: one towards the reduction of behaviour to simple elements by some such techniques as those of factorial analysis; the other towards the discovery of "critical points" of qualitative change and the construction of instruments that will record the reaching of them. These possibilities of advance he considers to be irreconcilable at present, although he does not overlook the possibility that some wider understanding may ultimately permit them to merge. He argues that meanwhile neither should be neglected, but he gives no more indication of how he thinks the second of the two might be pursued than he gave earlier in his book of how he thought the "underlying events" might come to be known.

It is with these questions that the next two chapters will be concerned.

CHAPTER II

Smith talks of coming to know the "underlying events" but the word "underlying" is perhaps unfortunate. It suggests obscurity and inaccessibility, and while it may be that what is to be studied is both obscure and inaccessible it would be wiser to avoid prejudging the issue and to employ a more neutrally descriptive term. "Preceding" suggests itself since we are evidently concerned with sequence. It is clear that thinking takes time and that results are in some sense arrived at. Beyond this it is also clear, to continue the almost inescapable spatial metaphor, that a given result may be reached by more than one route. It is the possible variations of route, with all the false turnings and retracings, that are to be studied.

Two questions at once arise:

Is the thinker himself aware of these preceding events?

And can an observer become aware of them?

The second question is much more important than the first for the purposes of this discussion, and it is not so dependent on the answer to the first as might appear. But the first deserves some brief consideration.

Though it has now been widely accepted that there occur in us mental processes of which we are unaware, it is only certain sorts of unconscious process whose existence is generally considered to have been established. I refer, of course, to the activities of the "forgotten" memories, the repressed desires, that constitute the

"unconscious" of the psycho-analysts. This "unconscious" is usually thought of as a kind of repository, having "contents" that influence our lives in active ways, but of whose activity we remain completely unaware. They are generally held to exert their influence chiefly on emotional and physical functioning. However, since it is evident that the thought processes of a person cannot be sharply separated from the rest of his being, it has to be allowed that if there are unconscious processes at all they must influence thinking¹ at least in an indirect way. But this admission of indirect influence would not make it necessary to suppose that our actual thinking process is in any sense hidden from us. We must therefore ask what direct arguments can be advanced for the existence of unconscious thought.

An obvious way to begin is by asking how it has been possible to produce evidence of the existence of the psycho-analytic unconscious. The answer is that this has been done in the only way that could conceivably be conclusive: by bringing the unconscious into consciousness. It is only when we succeed in pushing back the boundaries of the totally unknown that we can know there is anything there to know. Before this, of course, we may have strong logical grounds for suspicion. We may be able to argue that only

1. The activities of the psycho-analytic "unconscious" are, of course, sometimes considered to be themselves a form of thinking, but so long as they are distinguished from intelligential thought this becomes a question of definition only. I have considered it better to reserve the name "thought" for the latter. Piaget in "The Language and Thought of the Child" seems to adopt the other policy, for he distinguishes between "directed or intelligent" and "undirected or autistic" thinking, and to this distinction makes that between conscious and sub-conscious thinking correspond. But I have thought it unsafe, for the reasons given in the following pages, to claim that all intelligential thought is conscious.

the existence of something as yet unknown could explain what we observe. It was in this way that Leverrier discovered the planet Neptune. He argued that observed astronomical events could only be accounted for by the existence of a planet in a specified position, and it was subsequently possible to proceed to observations which confirmed his hypothesis.

In a similar way, it would be possible to reason that only the existence of unconscious thought processes could explain what we observe in the study of thinking; and this sort of argument has in fact been advanced. It is most frequently offered in connection with what is known, with amusing contrast of metaphor, as "inspiration" or "incubation". This is the fact, reported by many thinkers, that some of their best ideas seem to come suddenly "from nowhere". But the argument that only unconscious thought processes can explain this cannot be maintained. Several other reasonable hypotheses have been suggested - among them simple recovery from fatigue, or from interferences that have previously been blocking progress - and so long as these have not been disproved, unconscious thought remains, on this evidence, only one of a number of possibilities.

This same sort of argument was also used by the psychologists of half a century ago to explain some of their introspective findings. Ach, for instance, postulated the existence of unconscious "determining tendencies" to explain the way in which purposes lead to actions, and Binet argued that the "esprit critique" can function unconsciously in

the elimination of unhelpful ideas. The difficulty with such claims is that the kind of confirmation which the astronomers could obtain is not so easily obtained by psychologists. Leverrier's fellow astronomers could turn their telescopes in the direction in which he told them to look and see there the planet, as he had predicted. But in the case of thought what confirmation is possible?

It may be helpful to consider again the evidence for the psycho-analytic unconscious. If a person declares that he has become aware of some early event that he had quite forgotten, the truth of his claim may possibly be verified in two ways: by a confirmation that this event did in fact occur as he describes it (though this is verification of an extension of consciousness only if one accepts that the subject had indeed entirely forgotten the event); or by the fact that from this moment his behaviour is observed to change in a way that is fully consistent with his claim that he now has new understanding. Though the former kind of verification is not possible in the case of unconscious thought processes there is no evident reason to suppose that the latter may not be. If one became conscious of thought processes of which one had formerly been unaware it would seem probable that one's thinking would alter in ways that would be observable in changed behaviour; and presumably there might be either facilitation or impediment according to the nature and rôle of the processes concerned. It is possible to conceive of thought processes that would be more efficient when they were unconscious; for

it is well known that certain motor skills appear to be actually hindered by any attempt to think consciously about their performance. Here, however, a distinction must be made between noticing or not noticing what one is doing and crossing a real frontier between the accessible and the inaccessible to consciousness. In the case of motor skills there seems usually to be a gradual reduction of awareness as efficiency is acquired, but one can become aware again merely by "thinking what one is doing", so that this unawareness is very different from a real barrier of unconsciousness.

But though there are some acts which can best be performed unthinkingly after skill in them has been acquired, it seems certain that there will be at least one circumstance in which increased awareness - whether a real encroachment on the formerly unconscious or merely a better noticing - will tend to bring increased efficiency: and that is where the processes that were occurring unawares in some way involved error. A good example would be provided by any instance where reasoning depended on assumptions which the thinker was quite unaware of making, and which were mistaken. Until the existence of the assumptions was recognised the question of their soundness could not even be considered.

The history of thought is full of instances where the discovery and questioning of assumptions have led to new advances; but it is clear that these discoveries are not easy to make. It is not enough simply to ask oneself what are the fundamental assumptions on which a conclusion rests. The answer is far from being clear as soon as

attention is directed to the problem. This suggests that here we have an instance of something in thought which can indeed lie beyond the reach of consciousness. But, if so, the bringing to light of the "contents" of this unconscious would seem to be in some ways very different from the exploration of the psycho-analytic unconscious. The latter is usually conceived of as an advance in depth, but the former would be better thought of as an advance in height. The contents of the psycho-analytic unconscious were once conscious, at least in some degree, but were "buried" and have to be "dug up" again. Unconscious assumptions, on the other hand, have presumably always been unconscious, and coming to know them is like reaching a higher point from which one has a wider view.

It is clear, then, even from these considerations - though they raise only a few of the relevant issues - that a student of thinking processes would be quite unjustified in believing he could be sure that all the subjects of his investigation would be aware of the whole of their own thought. More important than this, however, is the question of the extent to which an observer can become aware of it; and this does not depend entirely on the answer to the first question because it is not an evident logical necessity that an experimenter should be aware only of such mental processes in his subject as the subject is himself aware of. A psycho-analyst would certainly claim to know of wishes and anxieties in his patient of which the patient had no knowledge at all.

The way in which the psycho-analyst would claim to come by this knowledge is important to consider. He would say that he does so by interpreting certain signs - signs which the patient himself can also observe but which he is unable to interpret: for instance his dreams. Now this claim appears to carry an important implication: that, in some measure at least, we know ourselves not with immediacy but through a process of interpretation that has very much in common with the way we know other people; so that it is not impossible for others to know us better than we know ourselves if they are more skilled interpreters.

An important part of psycho-analytic theory is of course the contention that when the patient cannot interpret the signs for himself it is because of certain emotional resistances. But this does not affect the general implication of the psycho-analyst's claim, namely that the gaining of self-knowledge is in some sense an interpretative process, and one which we can learn.¹

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1. Psycho-analysts might object to this on the grounds that talk of "learning to interpret" suggests an intellectual process that can occur in the absence of the full understanding they would call insight. It is of course true that any interpretation may be "intellectual" in a pejorative sense. There is always the possibility of a substitute for live understanding - and this is true of the psycho-analyst's own efforts to interpret his patient's behaviour. He may, himself, merely apply a formula. It is the ease with which a formula can be made to serve as a substitute for understanding that has given rise to the pejorative use of "verbal", as well as to that of "intellectual". But we would be acting very foolishly if this led us to reject words or scorn the intellect; or to suppose that all "learning to interpret" must be of this kind.

Strong support for this general notion comes from one who is not of the psycho-analytic company: C. S. Peirce, the founder of pragmatism in its original form and one of the first symbolic logicians. Peirce, in the course of a most effective attack on the Cartesian theory of innate ideas,¹ argues that we have to learn to know ourselves, and that we do this by a gradual process of learning to interpret signs - a process in which the discovery of ignorance and error are of central importance² and where advance depends on the criticism of other people and of that critical "other self that is just coming into life in the flow of time."³

In this way Peirce's arguments lead him to the interesting conclusion that introspection is not so much an undesirable method of investigation as an impossible one. When some-one claims to introspect he is in fact interpreting signs that are not essentially different in status from those which he would be interpreting in the course of studying another person.

Peirce argues in support of these ideas with great skill. But though they seem to invite the conclusion that there is no fundamental distinction between the methods of the "introspectionists" and those of the behaviourists since both proceed by way of the interpretation

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1. C. S. Peirce: Collected Papers, edited by C. Hartshorne and P. Weiss. Cambridge, Mass: Harvard Univ. Press., 1931. Vol. V. § 213 et seq.
 2. See, for instance, Ibid. Vol. 5, § 233.
 3. Ibid, Vol. 5, § 421.

Strong support for this general notion comes from one who is not of the psycho-analytic company: C. S. Peirce, the founder of pragmatism in its original form and one of the first symbolic logicians. Peirce, in the course of a most effective attack on the Cartesian theory of innate ideas,¹ argues that we have to learn to know ourselves, and that we do this by a gradual process of learning to interpret signs - a process in which the discovery of ignorance and error are of central importance² and where advance depends on the criticism of other people and of that critical "other self that is just coming into life in the flow of time."³

In this way Peirce's arguments lead him to the interesting conclusion that introspection is not so much an undesirable method of investigation as an impossible one. When some-one claims to introspect he is in fact interpreting signs that are not essentially different in status from those which he would be interpreting in the course of studying another person.

Peirce argues in support of these ideas with great skill. But though they seem to invite the conclusion that there is no fundamental distinction between the methods of the "introspectionists" and those of the behaviourists since both proceed by way of the interpretation

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1. C. S. Peirce: Collected Papers, edited by C. Hartshorne and P. Weiss. Cambridge, Mass: Harvard Univ. Press., 1931. Vol. V. § 213 et seq.
 2. See, for instance, Ibid. Vol. 5, § 233.
 3. Ibid, Vol. 5, § 421.

of observed events, to draw this conclusion would be to leave out of account the crucial consideration of the availability of these events for inspection by more than one observer. The question, then, is whether the signs which are available to us when we observe and interpret ourselves are also available - or can be made available - as signs on which others may exercise their interpretative skill, so that there may take place the process of discussion and amendment that leads to the agreement in which, to quote Peirce again, "the community ultimately settles down."¹

This question, when directed more specifically to the study of thought processes, amounts to asking whether the reports which a person gives of his thinking may be accepted as dependable signs, through the interpretation of which some knowledge of his thought may be obtained. And at this point another passage from Peirce becomes relevant - so relevant that it must be quoted at length:

"A man goes through a process of thought. Who shall say what the nature of that process was? He cannot; for during the process he was occupied with the object about which he was thinking, not with himself nor with his motions. Had he been thinking of those things his current of thought would have been broken up, and altogether modified; for he must then have alternated from one subject of thought to another. Shall he endeavour, after the course of thought is done,

1. Ibid. Vol. 6, § 610.

to recover it by repeating it, on this occasion interrupting it, and noting what he had last in mind? Then it will be extremely likely that he will be unable to interrupt it at times when the movement of thought is considerable; he will most likely be able to do so only at times when that movement was so slowed down that, in endeavouring to tell himself what he had in mind, he loses sight of that movement altogether; especially with language at hand to represent attitudes of thought, but not movements of thought. Practically, when a man endeavours to state what the process of his thought has been after the process has come to an end, he first asks himself to what conclusions he has come. That result he formulates in an assertion, which, we will assume, has some sort of likeness - I am inclined to think only a conventionalized one, - with the attitude of his thought at the cessation of the motion. That having been ascertained, he next asks himself how he is justified in being so confident about it; and he proceeds to cast about for a sentence expressed in words which shall strike him as resembling some previous attitude of his thought, and which at the same time shall be logically related to the sentence representing his conclusion, in such a way that if the premiss-proposition be true, the conclusion-proposition necessarily or naturally would be true".¹

This quotation from Peirce seems oddly at variance with some of his other contentions: for instance that "all thought whatsoever is

1. Ibid. Vol. 2, § 27.

a sign and is mostly of the nature of language."¹ Perhaps the explanation is that Peirce uses the word "thought" in two different senses: sometimes as process and sometimes as product. The above passage occurs in the course of an argument in which he is concerned to show that the logician's task is not to study the actual movement of thought but rather to criticise the results of thought. And since he remarks in the same connection that for all he knows or cares there may be a hundred ways of thinking in passing from a given premiss to a given conclusion, one might perhaps object that in this case he, as a logician, is hardly qualified to comment on the nature of thought processes at all. But this cannot be said of another writer who comes to express views that curiously resemble those of Peirce. The writer is Binet, in one of the last articles that he contributed to *L'Année Psychologique*² - a paper in which he reaches the conclusion that the error which above all must be avoided is that of seeing the mind as a succession of states and not actions. Thought is not a series of images, it is an act of understanding, of interpretation. The old theory of mental life was "so rational" and supposed that "all can be explained, all is co-ordinated, all can be justified ... that reasoning is composed of premisses and conclusions and that one deduces the conclusion from the premisses and cannot arrive at the conclusion without having passed by way of the premisses." In

1. Ibid. Vol. 5, § 421.

2. A. Binet: Qu'est-ce qu'une émotion? Qu'est-ce qu'un acte intellectuel? *L'Année Psychologique*, 1911, 17, 1-47.

contrast with this, the new theory is "a theory of action, according to which mental life is not at all a rational life, but a chaos of shadow crossed by flashes, something strange and above all discontinuous, which has appeared continuous and rational only because after the event it has been described in a language which brings order and clarity everywhere; but it is a factitious order, a verbal illusion ..."

If we study the reports that a person gives of his thinking, are we then exposing ourselves to the full force of this "verbal illusion"? Binet is not unaware of the irony of drawing his conclusion about the nature of thought from the results of introspective studies. His comment is: "Quel sujet de méditation pour ceux qui aiment philosopher!"

But there are two things to notice: first, that both Binet and Peirce are specifically concerned with the possibility of having some-one describe the course of his thinking; and secondly that this implies for them a report given after the event.

There is an alternative procedure which consists not in asking the subject to think and then describe but rather to make his thinking accessible to an observer by doing it "aloud". We must now ask whether this method is free of the disadvantages to which Peirce and Binet refer; and also whether, if it avoids these, it has any others in its turn.

In the first place, the change from asking the subject to "describe" to asking him to "think" seems to meet Peirce's objection - since frequently made by others - that if the subject has to describe what he is doing, his "current of thought" will be broken up and he will be unable to think uninterruptedly because of the need to watch himself thinking. But this same abandonment of the request for description has another advantage that may be at least equally important, for it at once removes any likelihood of resort to the complicated vocabulary of logical terms in which we are accustomed to describe thought, and which may be so misleading from the point of view of psychological, as opposed to logical, inquiry. If there is no call to "describe" there will be no need to talk of "such things as judging, abstracting, subsuming, deducing, inducing, predicating ..."¹ to quote Gilbert Ryle: terms which he says are appropriate to descriptions of results reached but which we all too commonly use in efforts to describe the ways in which we reach them. He goes on to claim that it is because of this, and because we do not catch ourselves performing these acts which we "describe" in this way, that we conclude that these acts must be "very subterranean happenings". And this might not be unjust as a comment on the conclusion of Binet's that has been quoted above.

So then if we avoid this sort of terminology we may perhaps reduce a little the disparity between the word and the act of which Binet and Peirce were so aware; and we shall certainly make it possible

1. Ryle, *Op. cit.*, p. 285.

to use the reports of a great many subjects who could never have told us they had been inferring or subsuming.

There is one further advantage that may be of some importance - one that derives primarily from the fact that when the subject "does" instead of "describing" his words are no longer retrospective. There is then no longer the same danger that they will misrepresent the course of thought because of the subject's forgetting what he did and being unable to retrace his steps with accuracy. But, on the other hand, it appears that in avoiding this risk we may incur another one. The finding of words may in itself affect thought, so that, though we no longer have the danger of inaccurate retrospection, we have altered the thought itself.

This would seem to be one of the two main objections that can be brought against the "thinking aloud" procedure. The other is that thought may be too quick for articulated speech, so that we can only know by this means some of the resting-places, and never the actual movement of the thought between them.

The force of the second objection depends on what one claims for the method. If one were to claim that by using it one could reveal the entire processes of thinking, then the force of the objection would be very great. But if one claims only that its use will enable one to discover more about the processes than would be possible from any study of the product, then the second objection is no longer valid; for even if one can know only resting-places, it is an

obvious advantage in mapping the route to have knowledge of the intermediate ones as well as of that which is finally reached when the journey is over.

The first objection cannot be dismissed entirely. Undeniably it may be true that when a subject thinks aloud he will think in a way that is different from that in which he would otherwise have thought. The best answer to a claim that differences occur which are of such a nature as to invalidate the method is, I think, to give a preliminary illustration of the kind of evidence which can be provided by verbal utterance in the course of thought.

In the illustration which follows, the words were spoken spontaneously and to this extent the situation is different from one in which "thinking aloud" is required. But numerous illustrations of the kind of evidence that may be obtained in the latter circumstance are provided in Chapter V of this thesis, where a report is given of studies in which the method of asking children to "think aloud" was employed.

The example¹ of spontaneous thinking aloud occurred in the course of the efforts of a girl of ten to do the Digit Symbol Test in the Wechsler Intelligence Scale. It should be added that there were reasons to suspect that she had some brain lesion, since EEG results revealed significant bilateral delta activity and spike discharges from the left hemisphere.

1. I am indebted to Miss J. F. Reid for this illustration.

In the test, subjects are first presented with the following key:

1	2	3	4	5	6	7	8	9
÷)	+	┌	└	√	(÷	┌

The test then consists in writing, below each one of a list of digits, the appropriate symbol. Before the test proper there is a demonstration list of seven items, three of which are completed by the tester and four by the subject, with help if necessary. In the course of doing these four, the girl commented on the difficulty of writing "L upside down" (see symbol for 5) but in spite of this managed to produce the symbol \lrcorner with some encouragement. She then completed, slowly but correctly, the first seven test items. The eighth digit in the series was 2. In order to find the symbol for this, she looked back to the key; and it was at this point that she provided the significant verbal clue. She exclaimed: "Two plus T" - oh dear!" - and immediately put her hand to her head in understandable distress and confusion. Now it is evident that the $+$ symbol for 3, and the \lrcorner symbol for 4¹ had combined with the digit 2 to form for her this pseudo-meaningful phrase. It is equally evident that it was the attempt to wrest meaning from this nonsense configuration which gave rise to the exclamation of distress. Her response leads me to wonder how often in school she had been expected to find meaning where she could see none.

1. Cf. her remark on "L upside down".

After a perplexed pause, she continued the test by copying the symbols in the order in which they are presented in the key, with no attempt to relate them to the appropriate digit. Then she announced that she had finished. When urged to go on, she resorted to writing in each blank the digit from the space above, and went on doing this until the end of the test.

It would obviously be too much to claim that the few words spoken reveal the entire movement of this girl's thought; but they do give an understanding of the nature of the breakdown that could not possibly have been gained from the study of her answer sheet alone.

Note on the method of "thinking aloud".

The method was first systematically used by Claparède, and called by him "réflexion parlée". He describes it and distinguishes it from introspection in his article in Archives de Psychologie, 1933, 24, 1-154; but he had previously indicated its use as early as 1917.

So far as I am aware, the only other psychologist who has made any extensive use of the method is Duncker. A report of the studies which he conducted with its aid is published as a Psychological Review Monograph (1945, Vol. 58, No. 5) in translation by Lynne S. Lees.

The reasons for this choice are several. In the first place, if one admits the method's limitations (see pages 30 and 31) one must allow that it may not be possible to discover by means of it what is the exact nature of the formation of hypotheses - as indeed Claparède found; and one must also acknowledge that some solution-phases may always escape observation. But errors are seldom; for while the very point at which thought "goes wrong" may not always be observable, the consequences are most unlikely to remain hidden for long.

This is perhaps only a special case of application of the general principle that the study of faulty functioning makes a better

1. This by no means led him to conclude that the method was valueless. On the contrary, he claimed it had very well revealed "les déviations de la pensée."
2. Duncker fully recognized this.

CHAPTER III

To decide that a study of thinking will be conducted by means of asking subjects to think aloud and then recording their words is not to have done with all procedural problems. Chief among the ones that this decision leaves untouched are those which concern the treatment of the protocols once obtained.

The nature of the analysis that is made of these will be bound to depend in large measure on the specific questions that the investigator tries to answer. For instance, it would be possible to look, as Duncker did, for "solution-phases"; or follow Claparède in attempting to study how hypotheses are formed. But in the experimental work which will be described in later chapters the guiding question has been: what errors did the subject make?

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 2. Duncker fully recognised this.

starting-point for inquiry than that of successful functioning, particularly when the subject of study is one of great complexity. The understanding of the healthy functioning of the body has waited on the study of pathology not only because of the great pressure to find remedies for ills.

But even if this were not so, and the only advantage of studying dysfunction lay in the urgency of practical problems awaiting solution, there would be no less strong a case to be made on these grounds for directing research efforts to the study of error in human thought. Ignorance of the nature of obstacles to progress is itself an obstacle to progress and the more we know about what impedes thinking the more likely we are to be able to devise means of removing impediments and giving the kind of positive help that will be of most value.

There are three main ways in which the study of errors may be of direct use in the development of intelligence testing. First, it may increase understanding of the manner in which the sorts of question at present in use actually function, and suggest modifications in the ways in which these are usually grouped and classified by the test constructors. At present, where tests include homogeneous sub-tests, the claim for homogeneity is generally based on obvious formal resemblances: all are "series" or "analogies" or something of the kind. But it has often been suspected that "psychological homogeneity" may in fact have a quite different basis, and the study of errors may reveal if this is so.

A second consequence of the study of errors may be that it will prove to have bearing on the realisation of the hope expressed by Smith (see page 15) that "underlying events" will be distinguishable on the evidence of final solutions once we have learned more about these events; and it may then become possible to construct problems in such a way that a certain kind of error is invited and others are rendered improbable. It has to be recognised at the outset, though, that "improbable" can never be replaced by "impossible" in this context.

Finally, the study may be able to contribute to the solution of the problem with which this discussion began and from which it may seem to have moved far: the problem of the sorts of question which should be included in an intelligence test. It may not be immediately apparent how it could serve this purpose, and in fact the belief that it might do so rests on an assumption that must be explicitly stated. But in my opinion the hope of finding theoretical justification for the choice of one sort of question rather than another rests on precisely the same assumption.

Before stating this assumption, I must make it clear that I am implying a distinction between "theoretical justification" and justification by follow-up alone, that is, by the demonstration that a test "works" with a certain measure of efficiency for a given predictive purpose. My reason for not calling the latter "theoretical justification" is that it provides no basis for predicting how well a

new and untried type of item will "work". It remains perpetually ad hoc. To say this is not to suggest that follow-up can be done without. Follow-up in some form is quite indispensable for the development and verification of theory. But it cannot serve as a substitute for theory.

The assumption, then, is that the acquiring of mental power is a process having order and coherence and advancing through a number of stages whose sequence¹ is constant from child to child. This is not to assume that each child learns everything in exactly the same order - a proposition that would be manifestly false. The assumption is only that there are certain central and crucial powers to be acquired - crucial because many subsequent increases of power depend upon them.

If this assumption is sound and such powers exist, then it is their presence or absence at a given age² that an intelligence test should be designed to ascertain. And it is to their discovery that a study of errors may contribute, because this study should be a means of revealing at any stage what is the necessary but absent basis of progress, how the things which the child cannot yet do are related to one another as failures of power. If it could be shown that at a given age one type of error commonly accounted for failure to succeed

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1. It is of course conceivable - and not incompatible with the argument here advanced - that there might be a number of more or less independent sequences.
 2. We must not, of course, take it for granted that speed of advance through the sequence of stages - if a regular sequence exists - is unvarying; or that the child who is furthest ahead at any moment will necessarily remain furthest ahead.

in a variety of different tasks then this would be strong evidence that a "critical point" had been discovered. Verification would lie in the study of subsequent growth of power - that is, in follow-up, though not of a massed, total score, group-average kind.

This will be more fully discussed in the following chapter. Here, however, it should be remarked that there is one great source of difficulty and complexity in the way of such a study: the fact that what is causing a child to fail to perform certain tasks successfully may be of a kind that would commonly be described as "non-intellectual". To take one obvious illustration, there is evidently a distinction to be made between a slip of the tongue or the hand and an error that arises from a failure to comprehend. Susanne Langer points out: "Every piano player, every typist, knows that the hand can make mistakes where consciousness entertains no error."¹ And every human being knows that so can the tongue. Freud, of course, has his theories about the sources of "slips". Whether he is right or not, it is evidently desirable to try to detect them and find means of preventing their occurrence. It may, however, prove to be very difficult for an investigator to tell in practice, even when the subject is "thinking aloud", whether a mistake has the status of a slip or not, since it is necessary to admit the possible occurrence of slips of the eye, the ear, and even of the understanding itself, or at the very least of the

1. Susanne Langer: *Philosophy in a New Key*, p. 29 (Cambridge, Mass: Harvard University Press, 1951)

memory. Something we "know quite well" may be forgotten; something we "understand quite well" may not be understood on a given occasion and in a given context. It is as important to recognise the existence of such complexities as it is not to allow them to prevent any study of thinking from ever being undertaken at all.

CHAPTER IV.

Although the existence of complexities must be recognised, it may occasionally be necessary for a time to disregard them or force a way through them, especially if one suspects that a vast intricacy of foliage conceals a relatively simple structure of trunk and branches. Something of this sort Piaget may be said to have done. Here is his own account of his policy, as given in his introduction to "Logic and Psychology":¹

"The psychologist ... welcomes the qualitative character of logic, since it facilitates the analysis of the actual structures underlying intellectual operations, as contrasted with the quantitative treatment of their behavioural outcome. Most "tests" of intelligence measure the latter, but our real problem is to discover the actual operational mechanisms which govern such behaviour, and not simply to measure it."

No criticism of this policy or lack of admiration for its remarkable successes is implied by the fact that this chapter will be largely concerned with suggestions for ways in which theories as to the nature of the "builder operations" of the mind, as Piaget elsewhere calls them, can receive both verification and application through attempts to study in detail their relationships to "behavioural outcome". Neither, it should hardly be necessary to add, is this intended to imply that Piaget did not arrive at his theories by way of the

1. J. Piaget: Logic and Psychology. (Manchester: Manchester University Press, 1953).

observation of behaviour. The fact that he did, however, does not reduce the need for the tracing of the journey back, which in its turn can be expected to contribute to further theoretical development.

The opinion has already been expressed (see page 39) that follow-up studies of individual children should be used for the verification of the hypothesis that a "critical point" in mental development has been discovered. These studies may be of two kinds. They may consist in what I shall call passive follow-up: that is, follow-up where the investigator does his best to make sure that all the children concerned have, so far as this can be controlled, the same "opportunities" in the period which falls between his first and second study of them, but where he makes no attempt at any active experimenting during this time. Sometimes this is the only kind of follow-up possible. For instance, if a study were intended to verify a prediction of school success under ordinary circumstances, as it so often has been, any intervention by the investigator would defeat the purpose. If, however, the research were intended to verify a theory that a critical point in the development of power had been discovered, then to take action based on the theory and designed to encourage the development would be a very good way of submitting the theory to test, provided that a parallel passive follow-up were also conducted. And if a major purpose of the whole inquiry were precisely to find ways of encouraging this development then active follow-up would obviously be indispensable. But it would be unlikely to be fruitful till much

preliminary work had been done, and if it were attempted too soon its results might too easily be dismissed as negative.

In addition to these methods of inquiry, there is another which may be of particular importance and value, though surprisingly little use has so far been made of it. But before this is described, attention must be drawn to an incompatibility which appears to exist between Piaget's views and those of Binet. The assumption that there exists a constant sequence in accordance with which the central powers of the intelligence develop¹ is at the heart of Piaget's theories. Against this assumption we have now to set Binet's famous opinion - subsequently endorsed by numerous clinicians - that "a defective child does not resemble in any way a normal one whose development has been retarded or arrested."² Binet goes on:

"The retardation of his development has not been uniform. Obstructed in one direction, his development has progressed in others. To some extent he has cultivated substitutes for what is lacking. Consequently such a child is not strictly comparable to a normal child younger than himself. So far as certain faculties are concerned, he remains at the level of a younger child; but in respect to others, he is on a level with normal children of his own age. An unequal and imperfect development is consequently his specific

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1. The theoretical importance of this assumption has been considered on pages 37 and 38.
 2. A. Binet and Th. Simon: *Mentally Defective Children* p. 13, (Translated by W. B. Drummond. London: Edward Arnold, 1914.)

characteristic. These inequalities of development may vary to any degree in different subjects."

Now if there were one developmental ladder of intelligence, each rung of which could be gained only from the rung below, then a defective child would equal in the actual extent of his powers at any given moment the younger "normal" children with whom at this moment he was sharing a rung. (This is not to say, of course, that he would equal them in his probable future climbing power.) So any such concept as this is clearly not in accord with Binet's opinion. If, however, there were a number of ladders, would this make reconciliation possible?

Piaget does sometimes talk in ways that would seem to be compatible with this latter conception. He allows for developments in parallel: for instance, of what he calls the logico-arithmetical operations on the one hand and the spatio-temporal on the other. But between these parallel developments he finds a close connection. His different ladders are not independent, "puisque ce sont les mêmes opérations, mais à une autre échelle."¹ In this case, any gross discrepancies of position on the different ladders would seem at the least improbable, and one would certainly expect the defective child to be retarded on them all.

Yet it cannot be denied that in clinical practice marked inequalities of development are often observed. And apparent inequalities even

1. J. Piaget: *La Psychologie de l'Intelligence* p. 173 (Paris: Armand Colin, 1947).

within the groups that Piaget brackets together - for instance "logico-arithmetical" - are of the most common occurrence.

The conflict may be partly resolved by the distinction made by Piaget himself in the passage quoted on page 41 - the distinction between underlying operations and behavioural outcome - if Piaget may be said to be studying the one and Binet the other; for the relationships between the two are obviously very complex. (For instance, behavioural outcome must include the effects of those "slips" of the tongue and hand that were briefly mentioned at the end of the last chapter.) And the conflict may further be seen to resolve itself into a question concerning status, as is obvious as soon as one asks: If two children are "equally unequal" in development, but differently unequal - that is, "backward" or "normal" in respect of different powers - are we to say they are equally intelligent? If we cannot always say so, then inequalities of development, though they will remain as clinical symptoms, will not necessarily be inconsistent with the notion of a central and invariable progression.

But when all this is said, it remains true that the inequalities are most marked, and at present, for the clinician, most perplexing. And one way in which they might be studied is by the explicit comparison of the "normal" child with the "retarded" older one and with the "advanced" younger one. If it were then found that some powers keep very much stricter pace with chronological age than others do, then inequalities both in the very dull and in the very bright would be

accounted for, and much light might be thrown on the significance of particular patterns of retardation and advancement.

Further, Binet's claim that one finds among defective children "peculiarities of understanding, reasoning, imagining which do not appear to have their equivalent in younger normal children" could be put to the test.¹

An interesting example of a comparison of this kind is provided by a study of reading processes conducted by Lloyd M. Dunn and recently published by Child Development Publications as a monograph of the Society for Research in Child Development.² Although in many ways valuable, this study is in one way of greatest value as a warning. The investigator begins by equating mental age in his two groups. Then, as a result of part of his study, he writes: "It seems reasonable to conclude, insofar as one is able from small samples and using a non-standardized measuring instrument, that educable mentally retarded boys in special classes are markedly inferior to normal boys of the same mental age in their ability to use context clues."³ From this one might conclude that mental age is independent of ability to use context clues, since it is possible for children to be equal in one and markedly different in the other. Yet the test of ability to use context clues consists of filling in blanks in sentences, the last of which "was very difficult, being modelled after the Minkus completion item on the Revised Stanford-Binet, Form L." And the mental age measure used was the Revised Stanford-Binet, Form L. If, then, the children are markedly

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1. A. Binet & Th. Simon: Op. cit., p. 13.
 2. Lloyd M. Dunn: A Comparison of the Reading Processes of Mentally Retarded and Normal Boys of the same Mental Age. Monograph of the Society for Research in Child Development, 1954, Vol. 19, No. 1.
 3. Ibid., p. 55.

different in respect of ability to use context clues we must surely regard with some caution the statement that they are equal in mental age. The questions which this experimental result invites but which do not seem to have been asked are, first: if the children in the normal group had been younger chronologically but of the same intelligence relative to their age - ideally, though of course impossibly, if the experimenter had been able to compare the performance of the retarded children with that of the normal group when the latter were younger - would he still have found differences? Or would there have been a point when the performances of the two groups were in fact equal? And again: if he waited till the retarded children were older, would a point ever come when their performance was as good as the original performance of the normal group?

The finding of answers to these questions (using new groups, of course, to investigate the first of them) would amount to an extension of the chronological age gap between the two groups in a search for limits of inequality. Perhaps no limits would be found especially in the case of the increase upwards. And, of course, analysis of errors might show that even when there was equality of score there remained differences of mental process that could not be considered trivial. One might find in the defective group those "absurd errors" to which Binet attached so much importance, and which he even tried to encourage because of what they revealed.

A further extension of the investigation of inequalities of development could take the form of the study of children known to suffer

from some specific sensory or cerebral defect: the spastics, the aphasics, the blind and deaf from birth. This is another way in which knowledge of the normal may be augmented by study of the abnormal and by subsequent comparison of the two.

Such studies would again be very relevant to Piaget's work because of his emphasis on the importance of the sensori-motor stages in the early development of intelligence. His theories suggest many questions to be asked about the development of those who suffer from serious sensory or motor disabilities: for instance, what is the effect of the spastic child's inability to manipulate objects with anything like the ease and skill of the normal child? If Piaget is right in stressing the importance of performance of the physical action, then the effect on the whole development of intelligence should be very severe.

In a recent paper in *Acta Psychologica*¹ in which he re-affirms the importance of manipulation and considers it in relation to the development of propositional thought, Piaget reports that he and his colleagues have been undertaking some studies of deaf-mutes, to see to what extent their disadvantages in the learning of any form of language have affected their thinking, holding it to the lower levels. He reports that features characteristic of the more elementary ways of thinking are found to subsist in their thought. Remembering the triumph of Helen Keller, one feels that it is wise to be cautious in discussing

1. Jean Piaget: *Le langage et la pensée du point de vue génétique: Acta Psychologica*. 1954, 10, 51-60.

the limitations that sensory defects impose. But it is evidently very important that more work of the kind which Piaget reports should be undertaken, both so that the nature of the limitations may be understood in relation to general theory and so that the handicapped child's efforts to overcome them may be helped in every possible way.

The studies that have been suggested in this chapter have one unfortunate characteristic in common: that they would be very laborious and time-consuming to conduct. But perhaps we shall have to accept that in the study of human thinking there are no short-cuts, and no substitutes for the most detailed observation.

I shall finish this chapter by mentioning one problem to which I do not at the moment clearly envisage the application of the methodological suggestions I have been making. The problem, moreover, is one that lies at the very heart of the general topic of the chapter: the study of the connection between mental operations and behavioural outcome.

Piaget tells us that he analyses the "structures underlying intellectual operations". But as soon as we attempt to pass from them to behavioural outcome we encounter the question of the availability of these operations for use in actual situations. We have to ask: if two people "possess" the same operations are they sure to be able to make use of them equally well when presented with a problem in the solution of which the operation has a part to play? The question of "slips" is again obviously relevant here. But the problem manifests

itself more generally also. Consider, as illustration, the following series:

1 0 2 3 3 8 4 _

If one observes by studying the first pair of digits that the quantity -1 is involved in the relationship between them, and if one then, in accordance with that principle of reversibility which Piaget declares to be the essential characteristic of organised and developed intelligence, recognises that the addition of 1 to the second digit of the second pair will facilitate the detection of the other relationships involved, one is likely to notice quickly enough that 2 is the square root of 4, and that 3 is the square root of 9 - whereupon one immediately has the whole principle of the series:

$$1^2-1, 2^2-1, \text{ etc.}$$

But in an actual experiment in which two people took part, one was able to solve this problem and the other was not, although both, beyond any question, had long since reached the stage of establishment of what Piaget calls "the group composed of the sequences of positive and negative whole numbers." The difference seemed to lie in the fact that one of them could make use of the +1/-1 transformation, while the other could not.

I do not propose to try to suggest here how such differences as this can be directly studied because it seems probable that the understanding of them must wait on many other discoveries concerning the nature of thinking. But until they are explained we are certainly not justified in claiming that we are close to a full understanding of human intelligence.

CHAPTER V.

The experimental work to be reported in this paper consisted in an application to the study of the problem-solving efforts of a small group of children of the "thinking aloud" procedure described and discussed in Chapter 2. For the reasons given in Chapter 3, attention was directed particularly to the study of the errors made. These, of course, might, and often did, occur in the course of thinking which finally led to a correct solution. To avoid confusion, therefore, the following terminology will be used throughout the report: "error" for any detectable flaw in reasoning whether leading to a right or a wrong conclusion and whether or not subsequently corrected; "solution" - right or wrong - for the conclusion finally reached; "answer" for the entire overt reply, including both the solution and the spoken thought preceding it.

Selection of the Experimental Group

Twenty children were chosen to form the experimental group. Each child had previously taken two Moray House Tests of Intelligence (M.H.T. 52 and 53) at an interval of a year, as part of the normal procedure for secondary school selection. The second test had been taken approximately four months before the investigation began. The standardised score of each child fell within the limits 115 ± 3 on each test, so that, as far as group test total score could indicate, they were of very nearly "equal" intelligence.



This seemed desirable because it was thought that a first study of the errors made by a small group of children would give a better indication of the worth of the method and of the further work that might most profitably be undertaken if the range of ability was narrow. Comparisons would then be easier to make and some indication would be gained of the extent of differences not revealed by the total group test scores. These differences would perhaps be of importance in later follow-up studies.

The choice of a range centring on 115 was, of course, arbitrary; but the score has a special claim to attention since it is so commonly taken as the selection "borderline".

The ages of the children were between 11 years 9 months and 12 years 3 months. There were 15 girls and 5 boys. It would have been preferable to have the age-range even narrower, and the proportion of girls to boys more nearly equal; but the test-score requirement, which was given priority, narrowed the possible choices so severely that a more rigorous insistence on age-equality and sex-balance would have made it necessary to draw the twenty children from almost as many schools. This in turn would have made the inquiry impossible, as it had to be done in a very limited period of time before the children were transferred to secondary schools.

As it was, the group was drawn from four schools, which will be referred to as K, L, M and N.

The following table shows the numbers taken from each of these schools:

TABLE 1.	<u>School</u>	<u>Boys</u>	<u>Girls</u>	<u>Total</u>
	K	3	4	7
	L	1	3	4
	M	0	5	5
	N	1	3	4
	Total	5	15	20

Procedure

The children were first given eight specially constructed group tests of twenty four questions each. Each test was "homogeneous" in the ordinarily accepted sense - that is, each was composed of questions of one formal type: analogies, classification items etc. The types used are listed on page 56 and the tests are given in full as an Appendix. All the types are currently in use in Moray House Tests. So far as was possible the questions were actually drawn from existing tests (excluding MHT 52 and 53, which the children had already taken) but in some cases a few new questions had to be introduced to make up the number; and in the case of Test VII an alteration was made. (See pages 84 and 85).

Group testing took place on two separate occasions, four tests being given on each. So as to eliminate any effect on average results of the order in which the tests were taken the children were divided into four groups and the tests to be given on the first occasion were arranged to form a Latin Square, thus:

Order of Tests.

	1.	2.	3.	4.
W	I	II	III	IV
X	III	IV	I	II
<u>Group</u> Y	II	III	IV	I
Z	IV	I	II	III

The four remaining tests, V, VI, VII, VIII, were similarly arranged on the second occasion of testing. It would have been possible to rotate tests I to IV with tests V to VIII so as to eliminate any effect of differences "between occasions" on the average results, but this would have had an attendant disadvantage: children might then have learned something from other children about tests which they were to sit on the second day.

Allocation of children to groups was random, except that care was taken to ensure that each school had - as nearly as possible - equal representation in each group. The allocation is shown in Table II (see opposite p. 58).

Eleven minutes was regarded as the standard time for each test, since in a full Moray House Test of 100 questions the time allowed is 45 minutes. After eleven minutes the children were asked to draw a line under the last completed question. They were then allowed to continue. Circumstances made it necessary to impose a final limit of 18 minutes but in all but a few instances this was more than enough to allow all questions to be attempted. Timed and virtually untimed scores were thus obtained.

This preliminary group testing served both as a guide¹ to the selection of the problems which were later to be given to the children during interviews, and as a means of ensuring that the interviews would be conducted not by a complete stranger but by someone whom the children had met on at least one previous occasion.² Also of course it was of interest in its own right as a further indication of the children's ability.

When the group test results had been studied, a list of fifteen problems was prepared and each child was interviewed and asked to solve these problems, "thinking out loud" as he did so. Everything he said was written down, pauses being noted. Occasionally he was asked to explain something he had said, but otherwise interruption was avoided as far as possible. Each interview took approximately an hour. The children were told at the start that the purpose of the inquiry was not to assess their ability but "to find out how to make better tests", and they seemed to accept this without question. Also they knew by this time what the results of the selection procedure had been. The selection "borderline" in Edinburgh is below 115, so by far the greater number had been allocated to full senior secondary courses. Those who were not to take such courses had preferred not to do so. No child appeared to be unduly anxious or in any way antagonistic to the testing.

-
1. See page 64.
 2. I conducted all the interviews and at least the first testing session at each school. The time in which the experimental work had to be completed was so short that it was necessary to have some help from students in the Diploma in Education class for the rest of the group testing.

The Group Tests Used.

Test I: "Alphabet" questions. (The alphabet is printed with these questions for reference.)

Example: "If all the letters of the word G I B E were removed from the alphabet, which would be the sixth letter of those remaining?"

Test II: "Elimination" questions.

Example: A, B, C, D and E are five girls.

A and E are tall; the others are short.

C, D and E swim; the others do not swim.

A and C play tennis but not golf; the others play golf.

Which of the tall girls plays tennis?

Which of the short girls does not swim?

Which two girls play golf and swim?

Test III: Analogies.

Example: Fire is to heat as lamp is to ..

(flame / candle / see / light / soot / dark)

Test IV: Classification items, where the exclusion of terms which "do not belong" is called for. (This type of question will be referred to as "classification (excl.)")

Example: Find the two that are most like each other but different from the others and underline them:

Foot / pound / minute / inch / gallon

Test V: Alphabet series. A printed alphabet is provided.

Children are instructed to find "the rule which tells how one letter or group of letters is found from those coming before or after it" and then complete the two blank spaces.

Examples: H, K, N, --, --.
 ZN, YM, XL, --, --.

Test VI: Classification items, where the class name is to be picked out from a list of class components. Children are instructed to find "the general word which describes the others".

(These will be called "classification (naming).")

Example: Rake / saw / hammer / chisel / tool / hoe

Test VII: Coding questions.

Example: Below are five words in a secret code.
 They mean:

WHILE, SMILE, WHALE, ALIVE, WHEAT

but not in that order. By comparing them, especially their beginnings and endings, you can find the meaning of each. Write the meaning in the brackets.

1. Y J C N G (WHALE)
2. U O K N G (SMILE)
3. C N K X G (ALIVE)
4. Y J G C V (WHEAT)
5. Y J K N G (WHILE)

T A B L E II

SCHOOL	PUPIL	GROUP	Alphabet I			Elimination II			Analogies III			Classification IV (excl.)			Alphabet Series V			Classification naming VI			Coding VII			Related Series VIII			Totals			Child Means			S.Devns.		
			T	U	d	T	U	d	T	U	d	T	U	d	T	U	d	T	U	d	T	U	d	T	U	d	T	U	d	\bar{x}_T	\bar{x}_U	\bar{x}_d	T	U	
K.	1	Ian	W	22	23	1	9	17	8	23	23	0	18	18	0	19	20	1	18	18	0	0	0	0	19	19	0	128	138	10	16.00	17.25	1.25	7.21	6.85
	2	Irene	W	19	19	0	17	17	0	20	20	0	16	16	0	17	17	0	23	23	0	15	15	0	20	20	0	147	147	0	18.38	18.38	0	2.45	2.45
	3	Carole	X	16	21	5	17	18	1	21	21	0	18	18	0	11	20	9	23	23	0	4	17	13	21	21	0	131	159	28	16.38	19.88	3.50	5.83	1.90
	4	Douglas	X	12	14	2	6	10	4	22	22	0	20	20	0	7	13	6	24	24	0	0	4	4	13	18	5	104	125	21	13.00	15.62	2.62	7.95	6.24
	5	Pat	Y	17	23	7	15	21	6	23	23	0	16	16	0	21	22	1	24	24	0	17	17	0	19	19	0	152	165	13	19.00	20.62	1.62	3.12	2.78
	6	Morag	Y	20	23	3	15	15	0	20	20	0	16	16	0	20	20	0	23	23	0	16	16	0	13	18	5	143	151	8	17.88	18.88	1.00	3.14	2.93
	7	William	Z	17	18	1	8	12	4	18	18	0	23	23	0	23	23	0	23	23	0	23	23	0	0	1	1	135	141	6	16.88	17.62	.74	8.02	7.28
L.	1	William	Y	21	22	1	17	17	0	20	20	0	17	17	0	18	18	0	22	22	0	19	19	0	12	13	1	146	148	2	18.25	18.50	.25	2.90	2.78
	2	Anne	W	22	22	0	20	22	2	24	24	0	20	20	0	22	22	0	24	24	0	24	24	0	23	23	0	179	181	2	22.38	22.62	.24	1.58	1.32
	3	Nancy	X	20	24	4	7	11	4	20	20	0	21	21	0	19	24	5	21	21	0	12	12	0	15	15	0	135	148	13	16.88	18.50	1.62	4.78	4.82
	4	Rita	Z	21	24	3	15	20	5	23	23	0	17	17	0	24	24	0	23	23	0	15	24	9	19	22	3	157	177	20	19.62	22.12	2.50	3.43	2.32
M.	1	Jeanette	Z	22	23	1	8	15	7	24	24	0	24	24	0	13	17	4	23	23	0	10	15	5	23	23	0	147	164	17	18.38	20.50	2.12	6.38	3.81
	2	Pat	Z	14	14	0	7	11	4	22	22	0	16	16	0	5	17	12	22	22	0	10	12	2	12	14	2	108	128	20	13.50	16.00	2.50	5.92	3.90
	3	Fay	Y	15	22	7	6	9	3	20	20	0	21	21	0	21	21	0	23	23	0	11	20	9	9	10	1	126	146	20	15.75	18.25	2.50	6.02	5.14
	4	Linda	X	16	16	0	10	17	7	19	19	0	22	22	0	23	23	0	19	19	0	0	3	3	16	16	0	125	135	10	15.62	16.88	1.26	7.02	5.78
	5	Elizabeth	W	17	22	5	9	14	5	19	19	0	18	18	0	18	18	0	24	24	0	0	13	13	16	16	0	121	144	23	15.12	18.00	2.88	6.90	3.50
N.	1	Margaret	X	18	18	0	18	18	0	19	19	0	18	18	0	16	16	0	7	7	0	10	11	0	8	8	0	114	115	1	14.25	14.38	.13	4.71	4.61
	2	Pat	Y	17	20	3	16	22	6	22	22	0	20	20	0	17	21	4	23	23	0	11	20	9	16	16	0	142	164	22	17.75	20.50	2.75	3.60	2.00
	3	Margaret	Z	19	23	4	11	16	5	24	24	0	23	23	0	14	17	3	23	23	0	5	5	0	21	21	0	140	152	12	17.50	19.00	1.50	6.40	5.98
	4	Ian	W	24	24	0	9	19	10	22	22	0	22	22	0	22	22	0	23	23	0	15	24	9	23	24	1	160	180	20	20.00	22.50	2.50	4.90	1.58
Totals	x			369	415		240	321		425	425		386	386		350	395		435	435		217	294		318	337		2740	3008		342.52	376.00			
Means	\bar{x}			18.45	20.75		12.00	16.05		21.25	21.25		19.30	19.30		17.50	19.75		21.75	21.75		10.85	14.70		15.90	16.85		137.00	150.40		17.13	18.80			
S.Devn.				3.01	3.13		4.49	3.81		1.97	1.97		2.57	2.57		5.11	2.93		3.71	3.71		7.28	7.28		5.74	5.54		17.85	17.52		2.23	2.19			

T = Timed Scores; U = Untimed Scores.

* If Test VIII is omitted, the mean of this child's scores is 19.29(timed) and 20.14(untimed);

‡ If the scores of William (K7) are omitted, the mean of test VIII is 16.74(timed) and 17.68

the standard deviation is 5.20(timed) and 3.93(untimed). (See p.63)

(untimed); the standard deviation is 4.55(timed) and 4.29(untimed). (See p.60)

Test VIII: Related series, where the child is required to arrange items in serial order in accordance with a postulated regular serial relationship.

Example: "If all large coins were worth more than smaller ones, which of the following would be worth most?"

(a halfpenny / a sixpence / a shilling / a farthing / a penny)

"If all small creatures could travel faster than larger ones, which of the following could travel fastest?"

(snail / greyhound / shark / eagle / fly)

Of these, analogies and classification questions have probably the longest history and are still today very widely used by intelligence test constructors. Alphabet questions, alphabet series questions and "elimination" questions have been in regular use in Moray House Tests for a considerable time. Coding questions in one form or other have for long been included also, but the type used here has only quite recently appeared regularly. A few questions of type VIII have been used from time to time.

Group Test Results.

Table II gives the results of the group testing.

It was originally proposed to use analysis of variance to test the significance of differences between tests and between children, but

when the tables of results had been compiled it was decided by inspection¹ that the variance was not sufficiently homogeneous for this analysis to be legitimate.

However, the widely differing score variances were in themselves a result of some interest. The tests where scores tend to cluster most closely together are III, IV and VI (analogies and the two kinds of classification). The standard deviation of III is particularly small and no child scores less than 18 out of a possible 24. The same is true of VI except that there is one low score of 7 which, since the number of children is small, has appreciably affected the standard deviation. (If this score is omitted, the mean for Test VI becomes 22.53 and the standard deviation drops sharply to 1.57.) Test IV spreads rather more widely, several children having scored 16. In all three tests extra time has made no difference: timed and untimed scores are the same in every case. In fact most children had completed these tests and looked over their answers in five or six minutes of the eleven allowed for the timed scores. Many children said they found them very easy.

These findings lead to the question of whether items of these kinds in the current Moray House Tests can be affording discrimination at any point above the intelligence "level" of this group of children (c. 115, as judged by M.H.T. total score). It should be

1. I am grateful to Dr. D. N. Lawley of the Department of Statistics, University of Edinburgh, for his opinion on this matter.

noted, however, that the children had previously taken two Moray House Tests, so that there was presumably some practice effect; also that they were above the average age for taking the tests and that we are dealing here with raw sub-test scores for which no age allowance could be made. Further, since the Moray House Tests are not Vernier Tests designed to discriminate at high levels, but are rather intended to give equal discrimination over the whole intelligence range, the presence in them of some sets of questions which do not discriminate at all above a standardised score of 115 cannot be considered surprising.

Yet, in spite of all these considerations, this result does suggest that it might be important to make a particularly close study of the discriminating power of these types of question, particularly since they are so extensively used. (See also p. 62)

By far the widest spread is that of the scores on Test VII, where the whole range is used. Test VIII would appear at first to be runner-up for this distinction, since it also has one timed score of zero; but this one score was found to have resulted from a misinterpretation of test instructions, as will be explained in the report on individual testing (see p.109). It may, therefore, be misleading to include it. Without it, the timed mean for VIII is 16.74, and the untimed mean 17.68. Standard deviations are 4.55 and 4.29.

It will be observed that Tests II and VII have lower timed means and show bigger mean gains with removal of time limits than do

any other tests. Tests II and VII would appear to have this at least in common: that they necessarily involve a sequence of deductive steps, with progressive elimination of possibilities. Errors made on these two types of problem during the interviews were closely similar. (See pages 69 to 74 and 86 to 90; also final discussion, pages 138 and 139.)

It was important to discover whether group test results seemed to indicate that any school differences were present.

Although, for reasons stated, no complete two-way analysis of variance could be carried out, it was possible to take the total scores of the children and analyse variance between and within schools. When this was done the variance between schools was found to be non-significant. Similarly it was possible to test "between-school" variance taking the scores on one sub-test at a time, but again no significant differences were found.

Consideration of test means and variances was followed by a scrutiny of child scores. A quite cursory examination of Table II shows that these children, selected for homogeneity of total score on a Moray House Test, have widely differing total scores here. The range is 104 - 179 (timed) and 115 - 181 (untimed); and this corresponds to a range of mean scores of 13.00 - 22.38 and 14.38 - 22.62 respectively. It is unfortunate that the measure of statistical significance of differences between children which analysis of variance would have provided is not available. But even if it were it would

not answer the question which it would seem most important to ask: are these differences significant with regard to prediction of a child's future success in school? It is to be borne in mind that the tests used here are of kinds in use in current Moray House Tests, but here each type is receiving equal weight, whereas in the full Moray House Test weights are very differently distributed. The types which usually carry most weight in the full tests (in the sense that they are included in the greatest numbers) are here represented by sub-tests I, III, IV and VI. Now I, III, IV and VI are precisely the tests which spread this group of children least widely, and their timed mean scores for these four tests taken together are as follows:

K. 1	20.25	L. 1	20.00	M. 1	23.25	N. 1	15.50 *
2	19.50	2	22.50	2	18.50	2	20.50
3	19.50	3	20.50	3	19.75	3	22.25
4	19.50	4	21.00	4	19.00	4	22.75
5	20.00			5	19.50		
6	19.75						
7	20.25						

(* This is the child with the very low score on VI. See p.59)

It would seem, then, that something of this nature is happening: these children gain very similar scores on the test items which form the main part of any Moray House Test; they succeed in very dissimilar measure with other types of problem, but these are represented in the Moray House Tests in fairly small numbers and

considerable variety. It would appear that the closely similar total scores¹ are a result of real similarity in test performance on certain major types of question and a compensating, balancing effect produced by unequal performances on the remaining parts of the tests. (It should be remembered, of course, that a complete test contains a greater variety of questions than is represented by the 8 sub-tests here.)

The children vary considerably in the extent to which they are able to increase their total scores with extra time. One child (Irene K2) makes no gain on any tests; another (Carole K3) adds as much as 28 points to her total. (This is equivalent to a gain of 14.7 on a test containing 100 items and was made in 63.6% extra time.) Consider also, Anne (L2) and Ian (N4). On untimed score they are in very close competition for the highest mark, but there is considerable disparity between their timed totals since one gains 2 and the other 20 with timing removed.

Again, there is considerable variability in the amount of spread of children's scores. And while children's scores cannot properly be compared in respect of spread when they are scores on unstandardised tests, the differences are worthy of notice because they may prove to be of interest later in connection with follow-up studies. The highest standard deviation of timed scores is 8.022 - but this is for the child who, because of a misinterpretation of

1. It should be recalled that it was similarity of IQ on Moray House Tests that formed the basis for selection of the group.

instructions, scored zero on Test VIII (see p.109). When the standard deviations of his scores are calculated without Test VIII they are:

Timed: 5.202

Untimed: 3.928

The highest timed standard deviation then becomes 7.953 - that of Douglas (K4) who also has the lowest timed mean. And the lowest timed standard deviation is 1.575 - that of Anne (L2), who has easily the highest timed mean. There is not, of course, any necessary connection between low mean and high standard deviation: the scores might well be consistently low. (In this case of course if all scores were low it would be hard to see how the child had come to be included in such a selected group at all. As it is, Douglas (K4) has high marks on III, IV and VI, and particularly poor ones on II and VII.) But there is a necessary connection between a mean as high as 22.38 and a narrow spread of scores, because of the 'ceiling' of 24.

The Interviews.

The consistently high marks obtained by the children in tests III, IV and VI made it seem unlikely that it would be profitable to include questions of these kinds in an inquiry where interest centred on the study of errors. The same was true, to a

lesser extent, of test I, and after some consideration it was decided that only II, V, VII and VIII should be represented in the list of interview problems. This meant that time was available for inclusion of a few questions of other kinds. In the end the list was composed as follows:

- A: Elimination (Group Test II): four questions asked about the one set of data.
- B: Alphabet series (Group Test V): two with paired letters, one with single letters, the latter running in the opposite direction to the alphabet itself.
- C: Coding (Group Test VII): a group of five words.
- D and E: Two problems where a piece of information essential to the solution was not provided. The child had to say what it was necessary to know before a solution would be possible. Problems of this kind have never been used in Moray House Tests.
- F to I: Related series (Group Test VIII): four problems.
- J to O: Deductive problems of various kinds, some of them requiring deduction from "nonsense" premisses. A few problems of this kind are currently in use in Moray House Tests; but the actual questions used in this enquiry were specially devised for the purpose.

These problems will now be discussed one by one in the order in which they were given to the children, except that J will be considered

immediately after D because of a particularly close relationship between them.

Table III gives the solutions offered by each child.

Children will be referred to by Christian names accompanied by the school initial and number from Table III. In quotations of children's answers, round brackets contain words spoken to the child by the interviewer, and square brackets contain comments and explanations to the reader.

PROBLEM A: Five boys, Jack, Dick, James, Bob and Tom

go to five different schools in the same town.

The schools are called North School, South School, East School, West School and Central School.

Jack does not go to North, South or Central School.

Dick goes to West School.

Bob does not go to North or Central School.

Tom has never been inside Central School.

1. What school does Jack go to? (_____)
2. What school does Bob go to? (_____)
3. What school does James go to? (_____)
4. What school does Tom go to? (_____)

There seems to be little possibility of wide differences in method in this problem. The reasoning has to run: "He does not go to V, W or X; and he can't go to Y because we know so - and - so does; therefore he goes to the only one remaining, Z."

It would be logically possible to proceed by elimination of boys instead of schools - i.e. to say: who goes to South School? - not Jack, nor Dick etc.. But, as the question is framed, very little headway can be made by this means alone, and the wording clearly invites elimination of schools. However, occasionally there were signs of an attempt to eliminate boys, for instance Elizabeth (M5) in her answer to (3) says:

"That'll be Central - because Bob didn't go to North or Central, and Jack didn't go to Central and Tom was never in Central - so it must have been James that went there."

All the children showed that they had a general grasp of the principle of progressive elimination of possibilities. Here is an example of an efficient answer, with which subsequent quotations may be compared:

- Pat (N2): (1) "It's not North, South or Central, and
 Dick goes to West - so it's East.
 (2) Not North or Central, not East, nor West -
 so it's South.
 (3) Not West, South or East. [She repeated this.]
 I think it's Central. (Why?) Because Tom
 has never been inside Central.
 (4) Not Central, South or East or West - so
 it's North."

Four children made no errors at all in the course of dealing with these questions; nine went wrong at some point but corrected their errors and eventually produced the right solutions; the rest gave at least one wrong solution.

In the making of the following classification all detectable weaknesses in reasoning were noted, even where a wrong solution did not actually result, or where an error was made and subsequently corrected.

Notes on Errors in Problem A.

(1) One of the most common errors in this problem was incomplete surveying of the possibilities. This will be called "incomplete elimination". Here is an example:

Pat (M2): "He doesn't go to North, South or Central, so he goes to West."

The existence of the East School is forgotten or ignored.¹ When this error occurred it was usually, but not always, the East School which was neglected. Presumably this was because the East School is not actually mentioned in the four statements which are the starting-points of deduction.

It seems probable that if names that did not so readily form a set had been used this error would have been even more frequent. On the other hand it is just possible that a set might sometimes be misleading. In this instance, the idea of four points of the compass might lead to the neglect of one of the five schools. This would be interesting to investigate.

(2) Progress in this question depends in considerable measure on the child's ability to use his own solutions in answering further problems. Sometimes there was failure to do this.

1. And this, of course, involves contradiction of the premiss concerning Dick. See note (7), p. 73.

Pat (K5) (answering A2): "It's not North or Central, nor West because of Dick. That leaves South and East."

Pat had just solved A1 correctly by deducing that Jack went to the East School.

(3) There occurred, in the answers of seven children, what seems best described as a loss of hold on reasoning as it progresses. A conclusion is reached and then promptly contradicted, apparently because it has been immediately lost. (Only cases where the loss was almost immediate have been included in this category.)

Douglas (K4) (answering A3): "Not West, nor East, nor South - so that leaves Central, North and West - no, Dick goes to West. So Central, North - no, South, Central ... oh, dear! It's getting more complicated."

Douglas eventually gave correct solutions to all four interview questions, but his group test score for this sort of problem was low: 6 timed, 10 untimed. He remarked: "I find these difficult. Usually I think about them so long." No other type of error could be detected in his answers to Problem A. Notice that Douglas has the lowest total timed score.

(4) In one or two cases there occurred abandonment of reasoning. A child would proceed by deduction for some part of the way towards a solution and then suddenly resort to apparent guessing.

Elizabeth (M5) (answering A4): "Tom has never been to Central, so he must have been to North or South. It'll be South (How do you know?) I don't really know."

It should be added that Elizabeth had failed to answer A2 correctly, and thus did not have readily available the information which should have enabled her at this point to eliminate "South". But the significant feature of her response is the readiness with which, instead of attempting to get the information, she accepts a guess as a substitute for logical certainty.

This tendency will receive further comment later.

(5) Several children introduced irrelevant pieces of information. This did not necessarily produce error, but was liable to lead to confusion. In the following example, however, it appears as a real break-down of deduction.

William (L1) (answering A2): "Bob ..., it's not North or Central. [Pause.] South. (How do you know?) Well, Jack doesn't go to North, South or Central. Bob doesn't go to North or Central. Dick goes to West. Tom has never been in Central. So that leaves Bob to go to South."

William appears to have attempted to eliminate boys - that is, to establish that, since the other boys don't go to South School, Bob must. He succeeds in eliminating Jack and Dick, but then he makes the quite irrelevant statement that Tom has never been in Central School. This obviously tells us nothing about whether

Tom might go to South School. Of course, it is possible that William was failing to deal adequately with this negative, and was treating it as a positive statement that assigned Tom to Central School (see (6) below); but the fact that the statement is irrelevant at this point remains.

This example provides illustration of the manner in which different errors may interweave. William is also guilty of incomplete elimination since he makes no mention of James (who, of course, is not mentioned in the four premisses). Yet in spite of this William's final solution is the correct one. It has to be recognised that, particularly since his account of how he came to his solution followed a request for explanation, it is possible that he had had more justification for his conclusion than he was able to say.

(6) The statement: "Tom has never been inside Central School" was a special source of difficulty. It seemed to be much more troublesome to some children than the other negative statements in the form: X does not go to Y school. For instance, Margaret (N3) reaches a point where she is left with Tom and James on the one hand, and the Central and North Schools on the other. She then says: "If Tom has never been to Central, there is only one left. So James goes to North School". Rita (I4) uses almost identical wording in reaching the same conclusion: she, too, calls North School "the only one left". (Both girls later corrected this error.)

This raises the question of whether the difficulty is due to the wording, or to the nature of the problem situation itself. If the statement had read: "Tom does not go to Central School", would there still have been difficulty? Possibly there would, because although no similar difficulty arose in the handling of the statements: "Jack does not go to..." and "Bob does not go to...", they had to be used differently. They were direct starting-points for inquiries concerning their own subjects 'Jack' and 'Bob'. But here we have an inquiry concerning James (who does not appear in the statements) and the starting-point is a negative statement about Tom. Yet, if that statement had been quite straightforward - "does not go....." - there might have been less likelihood of error.

It is impossible to say at present, but this is a question which could very easily be investigated if two differently worded versions of the problem were used; and this would seem to be the kind of information with which test constructors should be equipped. Very little is known about the effects of small differences in wording. Another example of a similar kind will be mentioned later.

(7) It will have been observed that this problem could very readily involve the children in contradiction, either of one of their

own earlier solutions or of one of the given pieces of information.¹

Contradictions arose in various ways. Sometimes they resulted from incomplete elimination; sometimes from the use of previous solutions which were themselves wrong.

There appear to be great differences in the extent to which children are prepared to attempt to correct themselves when they notice contradiction. Some clearly regard a solution, once arrived at, as "taboo" - not to be touched further under any circumstances.

Here is an example of a girl who does correct herself. Instances of children who do not will be given later.

Anne (L2) (answering A1 and A2): "Jack - not North, South or Central, so cut these out. Only West left, that's the one.

[Error caused by incomplete elimination. Contradiction of premiss.] Now Bob - not to North, or Central - leaves South, East and West. If Jack goes to West - no! Dick goes to West! Then it must be East for the first answer. So Dick goes to West, Jack to East, Bob not to North or Central - that leaves South."

Anne had the highest score on this type of question in group-testing, and also the highest total group test score.

1. See, for instance, the example in Note (1), where the conclusion that Jack goes to the West School contradicts the given information about Dick.

PROBLEM B:

 A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

1. , Q, N, K,
2. XC, VE, TG, ,
3. KL, JK, IJ, ,

The questions chosen for use in this part of the investigation were selected after a study of the wrong solutions in the group test had suggested that many of the children had difficulty if the series ran in the direction opposite to that of the printed alphabet; and also - as might have been anticipated - that a double letter series usually gave rise to more trouble than a single letter one.

All the children showed that they had a general understanding of the principle of extending a series. There were, however, some differences in method. The main division was between those who tried to establish a principle, explicitly stated, and those who relied on rhythmic chanting thus: Margaret (N1):

B (1) "K L M N O P Q R S T - K J I H"

The same child solved B (2) by this method, treating it as two separate series. (She made the error of reversal of order, however. See note 2, p. 78) She was the only one to treat B2 in this way, but

chanting was very common in (3), where it seemed to be particularly helpful. Children who read aloud: "KL, JK, IJ" were usually able to continue: "HI, GH" without much hesitation. A count shows that 13 of the 20 children chanted Number 3 with little or no statement of principle (except perhaps a remark like "go back"). Of these, 10 were correct. Of the 7 who tried to state the full principle, 4 were correct. Most of the attempted statements were somewhat inadequate, like that of William (K7): "It's just one forward all the time - the first letter of what you did last time." It is hardly surprising that this did not help him much.

One other method difference is to be noted. It concerns question 2 where there was a division between children who established the "miss one" principle, and applied it directly, and those who, realising that the numerical series 3 : 5 : 7 : 9 was involved, laboriously counted 9, and then 11 letters from the beginning and the end. Six children were notably laborious "counters". One (Carole K3) actually tried at first to count the letters between X and C, between V and E etc.. This is probably worthy of special note, and further inquiry. The children in the latter group all **certainly** know that nine is two more than seven, but fail to act confidently on the knowledge. It is as if the equivalence $7 + 2 = 9$, though known, is not so firmly established as to be quite taken for granted, but still needs

confirmation; or as if the children fail to see that the 7 is part of the 9, so that when they count 9 it is the same 7 and 2 more. This suggests that there may be some connection with an error that was observed in other problems and described as "exclusion" or difficulty with overlap. (See p.95). It is obvious that counting from the beginning or end of the alphabet is time-consuming and also liable to lead to slips. It may be significant that among the six "counters" are the children who gained 12, 9 and 5 in the group test when the time limit was removed. On the other hand, some of the "counters" made no gain in score.

Notes on Errors in Problem B.

(1) As already mentioned, it was suspected from a study of group test results that some children have serious difficulty when direction is reversed, as in B1. In the interviews only two children actually gave a wrong solution that seemed to be due to directional difficulty, but three others showed signs of hesitation. It was noticed that the first space in B1 gave more trouble than the last. It seemed to be easier to read Q - N - K - H than to fill a blank space coming before Q with a letter which in fact comes after Q in the alphabet. If this is a general rule it could be of value to those concerned to devise series questions of varying degrees of difficulty.

Irene (K2) gives an answer which illustrates this:

"Q to N - two letters, N to K - two letters. So two letters back from Q - N. No! I don't think it could

be. H is the second one all right Two letters before Q - that's N."

(1) The final conclusion: "that's N", was spoken in a puzzled tone; but she wrote N on her answer sheet. Apparently the notion "before" or "back from" Q was too strong to be overcome.

This may be taken to provide another example of the inability, already mentioned in discussion of problem A, to reject one's own reasoning even where it is in quite evident conflict with some known datum. It is plain that Irene recognises that it is not really satisfactory to have the series read N, Q, N (There is no suggestion that she has envisaged the possible complicated series N, Q, N, K, N, K, H, K, H). Yet she will accept this solution, instead of concluding that she is wrong and examining her reasoning critically.

(2) In B2 and 3 there was sometimes reversal of the correct order of the two letters selected as solutions: LR was written instead of RL, and KP instead of PK. This may be a special case of the error discussed above in Note I. Possibly it would not have occurred at all in B2 if the series had been: CX, EV, GT, When it did occur the child was asked whether it mattered which letter came first. Only one child (Pat - K5) replied that it did not matter; and she added quickly: "Oh, well - here it's got the end one before the beginning. I didn't notice that." (Because correction of these errors was the result of such very direct questioning,

they are shown as wrong solutions in Table III)

(3) Miscounting of the "gap" was a common error. Sometimes it seemed to be due to concentration on getting the direction right. In these cases it was perhaps akin to the tendency to "lose hold" that was described in connection with problem A. More commonly it was due to inconsistency about the inclusion in the count of the final letter. Thus O might sometimes be said to be two letters from L, and sometimes three.

Jeanette (M1) says: "How far Q is from N - 3 places.

So another 3 from K will be G"

It looks as if the child is a victim of the ambiguity of the language she is using, and is not recognising that "3 places from" may be varyingly interpreted.

(4) There was failure on the part of one or two children to appreciate the overlapping nature of Series 3.

Linda (M4) says: "JK, IJ, GH, and EF."

Carole (K3) gives GH and FG as her solutions.

This error may have some affinity with the error described as "counting" and discussed on pages 76 and 77. Difficulty with overlap - of quite different kinds - occurs in many later problems.

(5) One child seemed to be applying a wrong principle.

Elizabeth (M5) gave, as her solution to (3), LI and MH.

She seemed to be moving out on either side of the pair JK, but her explanation was confused to the point of incoherence, and it was not really possible to discover how she arrived at this conclusion. Another child (Pat - K5) stated the numerical series in B2 as: 3, 5, 8, 9. She completely ignored the given item TG, and gave as her solutions HS and LR, which she changed to SH and RL after questioning. (See Note (2).)

PROBLEM C:

TRUTH, HUTCH, PATCH, PLACE, GRADE

- (c) Pat (K5):
1. R N C E G
 2. V T W V J
 3. R C V E J
 4. I T C F G
 5. J W V E J

In this problem there were marked differences of method.

These will be considered first in some detail.

(1) In the first method a few letters are identified by comparison.

Then words are identified by deduction from this.

Pat (K5): "Number (1) and number (4) must be 'place' and 'grade' because they have G at the end and the others have J. Number (5) must be 'hutch' because it has J at the beginning and the end. So U = W. Any other with U in it? 'Truth'. So (2) is 'truth' because it has W third. If V = T then (3) must be 'patch'. So (1) is 'place' because P = R. So (4) is 'grade'."

This answer will be seen to involve:

(a) Study of the frequency and position of occurrence of a letter in different words.

(b) Study of the frequency and position of a letter in the same word. (This is only possible of course when the same letter occurs more than once.)

(c) Utilisation of new information gained when the identity of a word has been established; thus, "hutch" is identified because of the double H, then from this identification comes the realisation that U = W, which in turn is used to identify "truth".

These are the three main ways of applying this general method. Some answers, like the one quoted, made use of all these means. Many depended principally on (a). (It should be noted that the instructions invite the use of 1(a).) Fifteen children used method (1) in some form. Two of these, however, supplemented it by other methods.

There are differences between children with regard to the use which they make of frequency and position clues respectively. Most, of course, use both, but there is a tendency for more attention to be paid to frequency. Sometimes this goes so far as to amount to a complete ignoring of position.

Ian (KL): "Number (2) has a lot of v's, so it must be one with two letters the same. That might be 'hutch' or it might be 'truth'." After a pause Ian did go on to use position clues to eliminate one of his "possibilities".

An example of unusual attention to position is the following from Pat (N2):

[Numbers (1) and (3) have been identified as "place" and "patch".
It remains to discover which is which.]

"The sign for A will be the third one back in one of them and second in the other. Number (3) has C as second letter and number (1) has C as third letter. So (3) is 'patch' and (1) is 'place'."

A noteworthy feature of this answer is that it predicts what "will be" and then looks for that which accords with the prediction. No other child did this. It suggests a confidence in the certainty of deducible consequences that was rarely observed during the interviews. Pat scored only 11 on the timed group test, but rose to an untimed score of 20. It is of interest to compare Pat's handling of this question with her answers to the later syllogistic problems. She gave the correct solution to problem O, hesitated between the correct choice and a logical fallacy distractor in problem N, and chose logical fallacy distractors in L and M. A discussion of her answer to N is on page 121.

2. Method (2) is similar to method (1) but is more thorough in the application of the principle of elimination. By this method it is first of all established that (1) and (3), say, must be "patch" and "place". The next step, however, is not to find out which is which, but to establish in a similar manner that (2) and (4) must be "truth" and "grade", and that, therefore, (5) must be "hutch". The procedure is repeated so that one word is "odd one out" every time, and is thus identified.

This method is quite sound theoretically, but is apt to be cumbersome in practice. Its successful use demands the ability to

retain a firm hold on deductions already made, and slips can easily occur. Two children used it exclusively without complete success; one other made use of it along with 1 (a) and (b) and was very successful indeed.

3. This method is also similar to method (1), but the swift deduction of word identity from knowledge of the identity of a few letters is lacking. Instead each letter is identified laboriously by "between-words comparison" and written in the appropriate space. In this way the words are built up gradually.

This procedure is obviously very slow. Only one child, Margaret (N3), adopted it and even she did not carry it through to the end, but made some inferences when words were almost complete. Her timed group test score on this type of problem was 5; she made no gain, however, when allowed more time. Scrutiny of her script reveals that she completed the first set of words correctly and then wrote nothing more until 18 minutes had passed. She did not adopt particularly slow methods in solving the other interview problems and she distinguishes herself by her successes in problems M and N. For her answers to these problems see pages 117 and 122.

4. Finally there were two attempts to establish a coding principle and one girl made some attempt at it while proceeding mainly by another method. It should be explained that there generally is no coding principle to be discovered in questions of this nature in Moray House

Tests; but for the purposes of this investigation it was thought desirable to introduce principles both in the group tests and in the interview problem to see whether any attention was paid to them. The code in problem C was accordingly based on the principle $A = C$, $B = D$, $C = E$ and so on.

Both children who looked for a coding rule started with the risky assumption that the coded letters must be alphabetically "near" the original ones. ¹ They happened, of course, to be right in this case; but both were, to begin with, satisfied with a very vague notion of "nearness". All went well for them till number (4) was reached. The correct answer to (4) is "grade", but though G is "near" I, H is even nearer. Thus both children began by identifying (4) as "hutch". The proximity of T and U strengthens this solution; but a comparison of the third letters completely undermines it. One child, Irene (K2), made this comparison and was sufficiently self-critical and flexible to abandon her original notion. In the course of correcting herself she did in fact arrive at an adequate statement of the true principle involved, thus:

"There's a letter between from H to J, from U to W, from T to V ..."

The other child, William (L1), though he paused and looked disturbed when he came to the third letter of number (4), could not abandon his original hypothesis. His answer will be considered

1. This might possibly be the result of familiarity with alphabet series in which nearby letters quite frequently provide the solutions.

during the discussion of errors.

There is one further word to be said about method. One or two children showed real awareness of alternative methods of procedure. For example, Douglas (K4) says:

"..... and we've had T, so V is T, so number (4) is patch."

Then he adds:

"You could also find it out with the 'h' at the end."

Some of the others, though not so explicit, showed by their answers that they had a fine, flexible appreciation of possibilities.

It is surprising that Douglas's group test script seems to indicate that he proceeded by a slow and laboured identification of each letter as in method (3). He made no errors but had only identified four words in 18 minutes. Perhaps, although he recognised the possibility of alternative methods, he did not realise that some ways would be quicker than others. He appeared to be helped by the personal nature of the interchange of question and answer in the interview.

Fourteen children identified all five words successfully. Of these, five made errors and either corrected them or, as may fairly readily occur in this type of question, were correct in spite of them.

Notes on Errors in Problem C

Errors were found to be closely similar to those made in

Problem A. This was of much interest, particularly because of the resemblance in score-pattern of the corresponding group-tests, II and VII. (See p. 61)

(1) Incomplete elimination of possibilities was noted in the answers of six children. For instance, Morag (K6) decides that "A is represented by V" because (3) and (5) have V as third letter, and "place" and "grade" have A as third letter. She has failed to take account of the fact that (1) and (4) have C as third letter and that consequently A might be represented by C.

(2) Failure to use information already gained did occur here as in A but on one occasion only. One child (Elizabeth - M5), having identified four words, proceeded to try to identify the fifth, letter by letter. It was plain that she did not do this in order to check the correctness of her previous solutions, because she did finally show surprise at the realisation that if four were correctly identified the identity of the fifth could be in no doubt. In point of fact she was wrong in two of her earlier solutions, but wrong in such a way that if she had identified the fifth as the only one left she would have been correct in this fifth placing - that is, she had placed the four correct words in spaces (1) to (4) although two of them were in the wrong order. (See note (4) below.) When she then tried to identify the fifth word letter by letter she found, of course, that this could not be done in a way that would accord

with her earlier decisions. But eventually, having realised that the fifth word would be the only one remaining, she gave the answer "hutch" and ignored the lack of accord. This then may also be regarded as an instance of the error referred to in note 6.

(3) There were one or two instances of loss of hold on reasoning, in the form of immediate contradiction of assertions made.

(4) Abandonment of reasoning occurred again, in one case very interestingly.

Elizabeth (M5): "There's two P's and the rest different - and two R's. So (1) and (3) must be 'patch' and 'place'."

This was apparently regarded as adequate identification, for the words were at once written in spaces (1) and (3) respectively. The order in this case happened to be wrong; but when the same procedure was repeated for "truth" and "grade" (two R's, two T's) the order happened to be right. "Hutch" was subsequently identified as the fifth one (see note (2) above) so that the score was three "correct". Observe that Elizabeth was guilty of the same kind of thing in Problem A.

(5) Irrelevant information was sometimes introduced. For instance, Anne (L2) having established that "hutch" and "patch" are (3) and (5) attempted to find out which was which. She spent some time on

repetition of previously established information about the letters which were common and which therefore could not assist in the making of a distinction. This again might have been an attempt to check previous conclusions; but there is an attitude appropriate to the process of checking that was not observed here. When one checks one is on familiar ground, one has one's answers and has only to arrive at them afresh. But Anne was hesitant:

" E means C, so V means T "

It seems likely that she not so much checking as searching around in an undirected fashion for a new point of departure.

(6) Finally there were three instances of failure to notice contradictions or of failure to re-consider solutions when contradictions were observed. It is often difficult to be sure whether a contradiction has been noticed or not, but the case mentioned in the discussion of method (4) (p.85) provides a good example of an occasion when it is possible to be confident that the child was aware of contradiction but did nothing about it.

William (L1) gave the following answer: "Number (1) - find which letter is nearest R - P! [Note: He might equally well have said 'T'.] Then find the nearest one to N - L! Then A is near C, and E's near C, and G is nearest E. That's 'place'. Now take number (2): T - R - U - T - H [reading out slowly] Number (3): P - A - T - C - H Number (4): H - U - [Long pause. Finally he was asked: What has gone wrong here? But he did not reply and in the end continued...] - T - C - H.

Number (5): G - R - A - D - E."

It is plain that William forced himself to continue because he could not abandon the hypothesis which had seemed to work so far, and begin again. In order to conclude that (5) was "grade" he must have been very firm in forcing himself to ignore his doubts. It is possible that the intervention when he was solving number 4 made him feel he must "do" something, and brought him to the point of continuing when otherwise he would have given up. The fact remains that he ignored his doubts instead of reconsidering his conclusions.

When he had finished he was asked why he had looked for letters near one another. He replied: "Because I just thought it would be that way." He was then asked: "Does it always have to be the same distance away?" He hesitated, looked uncomfortable, and said: "It would be better."

PROBLEM D.

We want to find out the ages of two girls called Jean and May. We know that a third girl, Betty, is 15, and that she is three years older than one of the two girls and five years older than the other. If we had one more piece of information we could calculate the ages of Jean and May. What is that piece of information?

(a) May 12, Jean 15

(b) May 10, Jean 12

(c) May 20, Jean 15

(d) May 18, Jean 15

(e) May 14, Jean 15

(f) May 13, Jean 15

The question, as it stands, divides children sharply into two groups; those who appreciate the nature of this rather unusual problem, and those who do not. Some of the children failed to understand that they were not being asked to discover the ages of Jean and May but only to say what additional information would be necessary before this could be done. Children who understood what was required of them did not have much difficulty in producing an adequate solution, though they differed in the ease and confidence of their explanations. Thirteen acceptable solutions were received.

Examples:

Morag (K6): "You need to know which is the youngest of the two."

Pat (K5): "If they put one of them ... I don't know ... if they said one girl was the older."

Nancy (L3): "What girl she was three years older than."

Pat (M2): "We need to know which is which."

When the problem had been considered each child was asked:

If May is older than Jean, what are the ages of May and Jean?

The solutions to this question are listed below, together with the numbers of children who gave them.

- | | |
|---|--|
| (a) May 12, Jean 10: | 12 children |
| (b) May 10, Jean 12: | 1 child, who corrected herself after being questioned. |
| (c) May 20 (15+5), Jean 12 (15-3): | 1 child |
| (d) May 20 (15+5), Jean 18 (15+3): | 2 children |
| (e) May 12 (15-3), Jean 7 (15- (3+5)): | 1 child |
| (f) May 13 (15-2), Jean 8 (15- (2+5)): | 1 child |
| (g) May either 12 or 10 (15-3, or 15-5) Jean 7 (15- (3+5)): | 1 child |
| (h) May 5, Jean 1: | 1 child |

Of the 12 children who gave the correct solution 9 had previously been successful in giving the missing information, while of the 8 who calculated wrongly 4 had been successful in this.

ERRORS IN THE CALCULATION.

(1) Treatment of an asymmetrical relation as a symmetrical one seems to underlie solutions (c) and (d). It is as if the reasoning runs: Betty is 5 years older than May, so May is 5 years older than Betty, so May is $15 + 5 = 20$. This was not made explicit by

any of the children who gave this solution, but one girl (Margaret - N1) did suggest by the words in which she explained what information was missing that she was regarding the relationship as symmetrical.

Her words were:

"You'd need to know which one was three years older and which one five years older." She then calculated, quite consistently, that May would be 20 and Jean 18.¹

The third solution in the above list is an interesting example of inconsistency. The "5 - year" relation is treated as symmetrical, the "3 - year" one as asymmetrical. This may merely indicate that the child's conception of the relationship is poorly established and fluctuating; but it might possibly be a function of the order in which the names appear in the problem. That is, the child might establish some link between the first-mentioned age interval and the first-mentioned name. If then, before being told that May is older than Jean, he has associated Jean with the 3-year interval and cannot dissolve this association, he would have to reverse the 5-year interval in order to satisfy the requirement

-
1. The problem was perhaps made more difficult by the fact that the children were told that May was older than Jean, yet they had to realise and remember that both girls were younger than Betty. Possibly if they had been told instead that Jean was younger than May they would have been more successful. Burt (J. Exp. Ped., 1919, 5, 121-127) reports results which accord with this suggestion. For instance, he finds that the problem: "C is smaller than B; and B is smaller than A. Is A greater than C?" is solved by more children when the question is changed to read: "Is C smaller than A?" It is, of course, ease of transition from one of these formulations to the other which constitutes full awareness of asymmetry. (See final discussion, p. 129).

that May is older. (See also note (2) below. It is just possible that solution (c) is an avoidance of the inclusion of one period within the other by the device of putting one above and one below the age to which they must both be related.)

Ian (K1) showed that the order in which the names appeared was of some consequence to him. When he was presented with the first part of the problem he managed finally to say that it would be necessary to know which girl was the older; but he then went on promptly to advance a theory as to which one would be the older, thus:

"I think Jean is 12 because she comes first. When my aunt talks about my two cousins she says the older one first."

This appeal to ordinary experience at once makes the problem a "real-life" one, and indicates the difficulty which many of the children found in answering questions by way of deduction from the "given". This will be particularly noticeable in some of the answers to logical problems to be discussed later. Few children were able to look on these as intellectual exercises. Nothing can be said at present about the significance of ability or inability to do this at this age; but the distinction may possibly be an important one.

(2) The second source of error in calculation was the failure to appreciate the overlap of the two age intervals: the fact that

the 3-year one is included within the 5-year one. This failure may alternatively be described as "exclusion". Solutions (e), (f), (g), (h) and perhaps (c) (see note (1)) seem to involve this error. It is seen in most pure and obvious form in (e). The girl who gave solution (f) attempted the division of 5 into 2 and 3, but this only led her further astray because it apparently caused her to allocate the 2-year interval wrongly, making May 2 years younger than Betty instead of 3 years younger, and in spite of this attempt at division she subtracted the entire 5-year interval from May's age to find Jean's.

Solutions (g) and (h) are puzzling. When Margart (N3), who gave solution (g), was asked to explain why she had concluded that May would be either 12 or 10 she said: "She'd be either 5 years or 3 years older than Jean." It would appear that she had calculated the age of the youngest child first by subtracting the combined intervals, $3 + 5$, from the age of the eldest; and that then instead of finding the age of the middle girl by subtraction of 3 from the age of the eldest (that is, by straightforward application of a piece of given information) she had attempted to proceed upwards from Jean's age and did not know how the eight years should be divided.

Solution (h) was reached by an extraordinary argument, too long to reproduce, in which repeated deducting of 3 and 5 took place.

(3) One girl began by asserting that there was no other information needed to solve the problem. She was then asked: "How old is May, then?" - to which she replied: "She's 12 . (How do you know she is not 10?) Oh! You would have to know which is 3 years younger and which 5. (Suppose you knew May was older than Jean?) Then May would be 12 and Jean would be 10."

This answer is of some importance. This girl had the actual calculation well under control, but she did not seem to realise that May and Jean could not be allocated to the two ages without some further piece of information. Her surprise when asked "How do you know she is not 10?" seemed completely genuine.

It is particularly interesting to observe that the girl is Elizabeth (M5), whose answers were quoted in the discussion of abandonment of reasoning in problems A and C.

Her apparent complete disregard for the entire problem of "which is which" in the instance just described suggests strongly that this type of error is not always a simple matter of conscious "guessing" or unwillingness to persevere, as it might have seemed from previous examples. On the other hand it is certainly sometimes true that a child making an unsubstantiated choice knows very well that it is unsubstantiated and will admit it if pressed. The main distinction that is here suggested is between those instances when the child is aware that he could not defend his choice and those when he is not, but it is possible that there may also be

a distinction to be made between instances where some positive but unconscious principle is at work and those where no principle at all is operating.

Further examples of this same tendency will be given later.

- (1) Tom is 3 ft. 2 ins. tall.
- (2) Harry is 4 ft. 10 ins. tall.
- (3) Harry is 5 ft. 0 ins. tall.
- (4) Tom is 4 ft. 10 ins. tall.
- (5) Harry is 5 ft. 2 ins. tall.

This problem was given to the children in the order indicated by the alphabetical sequence. It is discussed here because it closely resembles Problem B from the point in that problem where the child is informed that Tom is older than Jess and is asked to calculate the ages accordingly. In this case, however, the problem is in "multiple-choice" form that is, a set of "solutions" is provided, from which the child is to choose.

Eight children chose the correct solution. Of the eight, two had not even heard that Tom was older.

Notes on Remarks

(1) Example of an asymmetrical relation as a symmetrical one occurs very quickly in D. (See Problem D - answer (1)) Here is a particularly good example.

PROBLEM J: Tom, Dick and Harry are three boys. Dick, who is 5 feet 4 inches tall, is 6 inches taller than one of the other boys, and 2 inches taller than the remaining one. Harry is taller than Tom.

Therefore:

- (1) Tom is 5 ft. 2 ins. tall.
- (2) Harry is 4 ft. 10 ins. tall.
- (3) Harry is 5 ft. 0 ins. tall.
- (4) Tom is 4 ft. 10 ins. tall.
- (5) Harry is 5 ft. 2 ins. tall.

This problem was given to the children in the order indicated by the alphabetical sequence. It is discussed here because it closely resembles Problem D from the point in that problem where the child is informed that May is older than Jean and is asked to calculate the ages accordingly. In this case, however, the problem is in "multiple-choice" form: that is, a set of "solutions" is provided, from which two are to be chosen.

Eight children chose the correct solutions. Of the eight, two had made errors which they corrected.

Notes on Errors

(1) Treatment of an asymmetrical relation as a symmetrical one occurs very much as in D. (See Problem D - error (1)). Here is a particularly good example:

Nancy (L3): "Find one [i.e. a solution] you could take 6 inches off and get 5' 4". That would be 5' 10" - but it's not there!

[There was such evident distress at this discovery that I suggested she stop looking at the choices and try afresh to calculate the solution.]

Well, Harry is taller than Tom, so Harry is the one Dick is 6 inches taller than, so Harry is 4'10". Then Tom would be 5' 2"."

In this second attempt the asymmetry of the Dick:Harry relationship is recognised, but the Harry:Tom relationship is still being treated as symmetrical. "Harry is taller than Tom" is not recognised as meaning that Tom is smaller than Harry. It is almost as if "taller than Tom" is taken to mean "further away from Dick."

Another possible interpretation would be that "taller" is being regarded not as a relation but as a quality which Harry possesses to a greater degree than Tom, so that the "6 inches" must refer to the former and the "2 inches" to the latter. But since the problem clearly could not be attempted at all unless its relational nature were in some way comprehended it would seem more likely that the error is to be taken as a sign of inability to manipulate the particular sort of relationship that is involved.

(2) Again, as in D, there were several instances of difficulty with the 'overlap' - that is, the inclusion of one interval within the other.

Rita (L4): "So Tom is smallest - that's 4' 10" ... 2 inches smaller than the remaining one ... that's 4' 8". I must be wrong somewhere."

But Rita was quite unable to see where she was wrong.

Finally she chose one solution - number (3) - but could not justify it.

Some children were successful in establishing the sequence:

Dick - Harry - Tom, and appreciated that the gap between Dick and Tom was 6 inches. They then decided that Harry was 2 inches taller than Tom instead of realising that he must be 2 inches smaller than Dick. This resembles the answer given by one girl - Margaret (N3) - to problem D, and discussed on page 95. That this particular error is more common in J (occurring four times) is perhaps a function of the fact that the biggest interval is stated first. This may encourage calculation of the smallest height first, and an attempt to derive the middle height from the smallest rather than from the tallest. The grammatical subject of the sentence has, of course, been quite lost from sight when this occurs. It is interesting to consider what might be the effect of a change in the statement of the problem so that two short sentences were used and the subject "Dick" was repeated.

(3) Abandonment of reasoning in the form of disregard of the "which is which" problem also occurs again no less than four times, but Elizabeth (M5) seems to have learned from Problem D. Here is her reply to J:

"Tom is 4' 10" (Why?) Well..... 6" off 5' 4" is 4' 10" and Harry is taller than Tom - so Tom must be less than Harry. [Pause] Harry is 5' 2"."

On the other hand, Irene (K2) proceeds very much as she did in answering problem A.

"One of the boys is 4' 10" and the other 5' 2". So I think Tom is 5' 2" and Harry is 4' 10"."

It would be perfectly possible to regard this type of error as a case of ignoring information, for it does, of course, involve the ignoring of the statement that Harry is taller than Tom. But its distinguishing characteristic is the willingness to proceed directly to a conclusion. The question: which is which? does not seem to be asked at all.

Here is a case, though, where there is doubt and searching.

Carole (K3): "Take 6 from 5' 4" - that's 4' 10". Two inches taller than the remaining one. I'm near it, but I can't get it. One's 5' 4" and the other's 4' 10". Dick is 5' 4", Tom is 4' 10", so Harry is 5' 2" (How do you know it's not Harry who is 4' 10"?) I don't know, really - I'm just guessing. (You are told how you can find out) [She re-read the question.] Oh! If Harry is taller than Tom he is 5' 2".

It is possible, of course, that though Carole said she was "just guessing" she had seen the reasoning at some earlier point in her thinking and then lost it but retained the conclusion. However at the point of final choice she was certainly aware of inability to defend it.

(4) This problem provided only one clear example of loss of hold on reasoning. Anne (L2), having concluded that Tom was 4' 10", was talking a few seconds later of Harry's height as being 4' 10", and going on to deduce that Tom was 4' 8".

(5) The "multiple-choice solutions" provided much opportunity for acceptance of contradiction, and there were further instances of the inability to reject one's own solutions even when contradictions were observed (cf. A(6) and C(6)).

Pat (M2): "If Harry is taller than Tom, Tom can't be 5' 2" tall - so number (1) is wrong. 'Harry is 4' 10"' is right. Number (3) is wrong. 'Tom is ...' (What's the matter?) Harry and Tom can't both be the same, so that means number (5) is right, because it is the only one left. [She showed no sign of recognition of the impossibility of Harry's being two heights at one and the same time, and seemed quite prepared to give (2) and (5) as her answer. But I decided to press her, and asked: Is that true then?] Well, if Dick is 5' 4" and he's tallest Harry must be 4' 10" and Tom must be 4' 8". [Overlap] so there's only one of them right. So number (2) is true, but it's the only one."

This girl had been told before beginning that two solutions were true, yet she would reject this instead of re-examining her own reasoning.

An example of apparently unnoticed contradiction is: "Dick's tallest, Tom is smallest. So Harry is 6 inches less than Dick - that's 4' 10" - and Tom is 5' 4" less 2" - 5' 2"." This answer was given by Margaret (NL).

PROBLEM E:

Detective-Inspector Nitwit is investigating a murder. He suspects that Joe Crook may be the guilty man. The body was discovered at 7 p.m., and Joe is able to prove that he had been at a friend's house from 5 p.m. until 7.30 p.m.

Detective-Inspector Nitwit is satisfied with Joe's alibi. But what do we have to know before we can say whether he is justified in accepting it?

.....
.....
.....

Only three children saw the point of the problem immediately. The remaining seventeen began by saying that it would be necessary to know whether Joe had indeed been at his friend's house from 5 p.m. till 7.30 p.m. (Notice that this is in spite of the use of the word "prove" in the third sentence. This suggests that it might be very interesting to study the development of the concept of proof at this age.) Two of the seventeen went on quickly to realise what information was missing. The remaining fifteen did not do so until their attention had been drawn again to the third sentence and some needed still further help and encouragement. Carole (K3) observed at the end:

"It just shows you don't read these things."

Four children had to have the meaning of "alibi" explained to them.

The following answer is a good example of the common pattern.

Ian (KL): "If I was a detective I'd go to that man's house and see if he said the same as Joe. (If it was true that Joe was at his friend's house from 5 till 7.30. would you know that Joe wasn't the murderer?) Yes, if it was true you would know. (Look again at the third sentence.) Oh! I see it now! This didn't mean he was murdered at 7 p.m. If I was a detective I'd get a doctor to tell me when he was murdered."

PROBLEM F: If all fast-moving animals were smaller than slower-moving ones, which of the following would be the largest?

(cat / snail / horse / squirrel / elephant)

PROBLEM G: If all rough cloth were thicker than smoother cloth, which of the following would be the thickest?

(silk / blanket / sacking / nylon / velvet)

PROBLEM H: If all light-coloured foodstuffs were sweeter than darker-coloured ones, which of the following would be the sweetest?

(honey / treacle / jam / brown sugar / milk)

PROBLEM I: If all small articles weighed less than larger ones, which of the following would be heaviest?

(an alarm clock / an iron / a cushion / a teacup / a nail)

PROBLEMS F TO I:

A problem of this sort demands the acceptance of a statement that two qualities, each varying continuously between two extremes, are perfectly correlated. The correlation may be one that is found in some measure in reality, or there may in fact be no real relationship between the qualities concerned.

In addition to acceptance of the statement, there must be recognition that of the two qualitative series one is, for purposes of solving the problem, independent and the other dependent; and further that it is necessary to arrange the alternative responses in series according to the independent quality in order to arrive at the correct solution. The independent quality is, of course, the one whose real possession is to determine possession of the other quality with which it is to be regarded as correlated.

The final step is to select the appropriate extreme of the independent series.

It is not, of course, suggested that this procedure is consciously in the minds of those solving the problems; but this analysis seems to make the errors which occur more readily understandable. The conscious formulation which most favours correct solution is probably something like: "Fast ones are small, so slow ones are big. That means 'find the biggest' equals 'find the slowest'." It is

certainly clear from the replies that it is particularly advantageous in these problems to begin by stating a definite objective: "Look for the roughest" etc..

The errors were of three main types.

(1) There was, first, inability to accept the statement where it conflicted with knowledge of reality. In no case was this inability total. It was very noticeably more difficult to lay aside knowledge of real size and weight than of real thickness and sweetness. For instance it was easier to imagine milk sweeter than honey than to imagine a cushion heavier than an iron or an alarm-clock.

Here is an example:

Ian (K1) Problem F: "Well elephant! (Why?)
Because it's slow and it's large, and if it was fast-moving it would be small like a snail."

Here there is clearly an attempt to accept the relationship fast-moving/small - but he chooses not the slowest animal, but one which is both slow and large. (The slowest of those which he classifies as large?) To Problem I the same child answers:

"An alarm-clock. (Why?) Because it's largest. (Is it larger than a cushion?) No, it isn't - no, 'cushion' is the answer. (Why did you choose alarm-clock?) I just thought in my mind: An alarm-clock would weigh heavier than a cushion."

Yet Problems G and H he finds quite easy, saying:

"Sacking, because it's rough and the roughest the thickest" and "Milk, because it's lightest".

(2) The following practice was observed in three instances: first the alternative responses were divided quite arbitrarily into two groups according to real possession of either the dependent or the independent quality. One of these groups was then selected as lying towards the appropriate end of the series and a final selection was made from within this group according to real possession of the other quality.

William (L1). Problem G: "Blanket, because blanket and sacking are rough, and the blanket is thicker than the sacking."

This boy starts with the independent series and ends with the dependent one. An example of the reverse procedure is given by

Fay (M3) in Problem F: "Horse and elephant are larger, the others are smaller If a horse is faster than an elephant that makes it smaller, so the elephant's the largest."

Errors of this type are evidently closely related to errors of the first kind because ordering in terms of the dependent series is in effect a failure to lay aside knowledge of reality; but they seemed sufficiently distinctive and noteworthy to merit separate classification. The practice of arbitrary grouping suggests that the notion of a continuous series between extremes may still be imperfectly developed so that things must be either "big" or "small" absolutely.

(3) Choice of the appropriate extreme often gave trouble, particularly when the statement of the problem contained a reversal, that is, when both extremes of the dependent series were mentioned.

Thus: "If small articles weighed less find the heaviest."

In these circumstances some children looked for the smallest article.

Morag (K6) Problem I: "A nail, because it's smallest."

But some children looked for the wrong extreme even when there was no reversal in the problem.

Pat (N2) Problem H: "Light-coloured sweeter than darker - got to find darkest. It's not jam or brown sugar ... No! We must find lightest. Milk!"

It will be recalled that during discussion of group test results it was stated that the zero score obtained by William (K7) on Group Test VIII (which corresponds to Problems F - I) was due to misinterpretation of test instructions. William scored zero because he underlined two of the possible solutions to group test questions, instead of one.

During interview he was asked why he had done so. He replied: "Because it said: 'Which would be the largest?' and so on, and 'largest' is plural." He appeared to have the idea that if only one choice had been required the form "larger" would have been used. He had all four interview problems of this sort correct.

PROBLEM K: My brother has one brother.

He has no sisters.

- Therefore:
- (1) He is sometimes lonely.
 - (2) He is rather shy.
 - (3) I am a girl.
 - (4) I have two brothers.
 - (5) I am a boy.

The first two distractors in this problem may be described as "common-sense" distractors. They are in the nature of remarks which might be added casually and conversationally to the statements that form the premisses. There is no logical link, not even a faulty one. In the syllogistic problems that follow, distractors are generally divided into two groups: "common-sense" and "logical fallacy" distractors.

It was considered that it might be of value to observe which of these would prove more attractive to children who failed to find the correct solution.

In this case the "common-sense" ones notably failed to distract. Nine children gave the correct solution, ten chose response (4) and the remaining boy said both (4) and the correct solution were "right". The only distractor apart from (4) which even gave rise to hesitation was number (1).

Here are a few examples of reasons given in support of the choice of number (4):

Douglas (K4): "I have two brothers! That means this one [pointing to the words 'one brother' in the premiss] must be my brother too."

Rita (L4): "I have two brothers. (Why?) Well, if my brother has one brother I must have two."

Fay (M3): "Number (4) (Why?) Because it's a brother that's speaking and his brother has one brother - so that's two."

Margaret (N3): "Number (4) (Why?) Because if you have one brother and then another you have two."

Reasons for choosing (5) generally took the form of explanation why (1) to (4) had been rejected. Some reasons for rejecting (4) were:

William (L1): "That wouldn't do because one brother would be me."

Jeanette (M1): "He has only one brother, so I must be his only brother."

Linda (M4): "You can't have two brothers if there's only two of you."

Ian (N4): "Well it's me that's talking, and I'm my brother's brother, so I can't have two brothers."

Reasons given for rejecting (1) and (2) often showed that these did not seem to the children wholly irrelevant, though they were never considered satisfactory.

Ian (K1): "Well, he can't be lonely with another brother."

Linda (M4): "He won't be lonely or shy if he has a brother."

No one showed any sign of amusement or scorn in considering these distractors. One reason for choosing (5) is interesting because of the personal "real-life" reference it contains.

William (K7): "'I am a boy' is right, for my wee brother has one brother, and I am the brother."

The choice of distractor (4) might be regarded as an instance of failure to recognise symmetry of relationship, but perhaps it is rather to be seen as yet another instance of "exclusion". The "I" is regarded as standing outside, separate.

Comparison with Problem J is possible. There, when exclusion occurs, the schema seems to be: B - 3 - 5,

instead of: $\left. \begin{array}{l} (B - 3) \\ (B - 5) \end{array} \right\}$

Here the schema seems to be: Me \rightarrow my brother \rightarrow his brother

instead of: $\left\{ \begin{array}{l} \text{Me} \rightarrow \text{my brother} \\ \text{"} \qquad \qquad \qquad \text{"} \\ \text{His brother} \leftarrow \text{my brother} \end{array} \right\}$

It is as if the schema stretches out in one direction, instead of doubling back on itself, or making two departures from the one fixed point.

PROBLEM L:

If all people who were born in July
were lazy, and Bob was lazy,

Then:

- (1) We would know Bob had been born in July.
- (2) Bob's teacher would tell him to try harder.
- (3) We would not know that Bob had been born in July.
- (4) Bob would not want to tell anyone when his birthday was.
- (5) Bob might learn to work harder.

PROBLEM M:

If all boys with red hair played
football well, and Tommy did not
have red hair,

Then:

- (1) Tommy would not play football well.
- (2) Tommy might still play football well.
- (3) Tommy would have no hope of playing in the school team.
- (4) Tommy would probably play other games.
- (5) Tommy would wish his hair was red.

PROBLEMS L AND M.

These two problems are very similar. Each is an attempt to test the ability to make a logical inference without the support of any experiential confirmation. In both cases the major premiss is not in fact true; so the child's knowledge of the real state of affairs cannot be mistaken for genuine deduction. The premisses are in the form "If..." It seemed probable that this would help the children to realise their hypothetical nature.

In both cases one distractor is an expression of the logical fallacy of the "undistributed middle": the child is tempted to accept as valid the simple conversion of the major premiss ignoring the fact that the predicate is undistributed. The correct solution offered is simply a denial of the fallacious conclusion reached in this manner.

Although they differ a little, all other choices will be referred to as "common-sense distractors" (see page 110). In both problems one of them is no more than a very general comment on the situation ((5) in L and (4) in M). Distractors (2) and (4) in L, and (5) in M - though also in the nature of comment - may be considered to involve the acceptance as premiss of some further proposition that the children take for granted. For instance, (2) in L may be said to rest on acceptance of a proposition to the effect that: "All teachers are people who tell lazy boys to work harder." And, of course, L (2) virtually ignores the stated major premiss. Finally, in M, distractor (3) does depend on acceptance of the logical fallacy but it is worded in a "common-sense"

fashion. Children who are really deducing logically but fallaciously are hardly likely to prefer it to distractor (1). (In fact though (3) was sometimes declared to be "true" it was never finally offered as a solution.) Ten children chose the logical fallacy distractor for both items. Seven chose the logical fallacy for one problem and a common-sense distractor for the other. One child chose common-sense distractors for both. Two chose the correct solution for one problem and the logical fallacy for the other. Also three of the children who chose wrong solutions showed some sign of recognition of the correct solution in Problem M.

The most common reason given for choice of the logical fallacy was that it was obvious. Sometimes premisses were simply read aloud, along with the "conclusion" as if that spoke for itself and there was nothing more to be said. Sometimes, however, reasons for rejection of the other four possibilities were given. Examples of those are:

Problem L, distractor (2).

William (K7): "His teacher would know his birthday and wouldn't bother to tell him to work harder."

Margaret (N3): "Because it's a different subject. It's about Bob's teacher and we were talking about Bob."

Problem L, distractor (4).

William (K7): "Everyone would know when his birthday was anyway."

Problem M, distractor (3).

Linda (M4): "Number (3) might do - but I think (1) is better (Why?) Because even if you can play well you still don't always get in the school team." [Therefore he might have no hope of playing in it even if his hair were red, therefore his having no hope is not a consequence of his hair colour?]

Problem M, distractor (5).

Margaret (NL): "It doesn't say he would want his hair red."

Linda's rejection of distractor (3) in Problem M is interesting as an objection to the implied logical sequence. Margaret's rejection of L (2) is an example of insistence on relevance - an insistence that was by no means rare. Several of the children seemed to be searching, somewhat gropingly, for criteria of relevance.

Reasons for accepting common-sense distractors are also interesting. Irene (K2) chose M(5) because "(3) is true as well and if he would have no hope of playing in the school team he would be sure to wish his hair was red". She appeared to be endeavouring to incorporate both choices in one!

Another reason was: "I'll take (5) - because I would wish my hair was red." This was given by Douglas (K4).¹

1. A number of investigators have studied the influence on the ability to make logical inferences of attitudes towards conclusions. See I. L. Janis and F. Frick: *J. Exp. Psych.*, 1943, 33, 73-77; A. Lefford: *J. Genl. Psychol.*, 1946, 34, 127-151; J.J.B. Morgan and J.T. Morton: *J. Soc. Psychol.*, 1944, 20, 39-59; D. Thistlethwaite: *J. Abnor. Soc. Psychol.*, 1950, 45, 442-458.

It was fairly common to find a child willing to accept as true all four distractors and rejecting only the correct solution, and sometimes in such cases there was considerable hesitation before a final choice was made. As already stated, only five children showed any interest in the correct solution at all - and in every case this occurred only in relation to Problem M. Whether Problem M is easier in some way or whether this is a practice effect it is impossible to say from the evidence available. These five answers to M are quoted in full.

Morag (K6): "I think the second one. (Why?) Because maybe it isn't that all boys ... maybe some other boys that didn't have red hair could play football too."

Pat (K5): "Then Tommy would wish his hair was red ... Well, the first one could be, too, in a way. And the second one could be too. [No apparent recognition of contradiction.] Even though he didn't have red hair he might still play football well."

Pat did not really know which of these to choose. She took (5) eventually - probably because of inability to decide between (1) and (2).

Fay (M3): "The first one. (Why?) Because ... [re-reading premisses] But number (2) might be - because maybe the boys without red hair could still play football well. (Why did you choose (1) then?) Because ..." [re-reading premisses.]

Margaret (N3): "Tommy might still play football well. (Why?) It doesn't tell you all the boys that hadn't red hair didn't play football well. I thought of (1) then saw it was wrong."

Rita (L4): "Number (1) (Why?) Well, it might be (2) - but if he didn't have red hair you would take for granted after that first statement that he didn't play it well. Yet he might still play it well. I think number (1), though. Is it just according to the statement? (Yes) I think (1), then."

The last of these is perhaps particularly significant. This girl is concerned about what may be called the genuineness of the argument. She does not see the point of making the first statement about the relationship between having red hair and playing football, and following this up by the statement about Tommy, unless the conclusion excludes Tommy from the group of boys who play football well. "Might still..." seems to her a feeble conclusion - as indeed in a sense it is. She has not yet reached the stage when her appreciation of strict logical development is stronger than her need to see the purpose of the argument. She is not able to regard this as an intellectual exercise. Her attitude is akin to that of insistence on relevance - as the child sees "relevance".

PROBLEM N:

- (1) NO ANIMALS THAT CAN ONLY MOVE SLOWLY CAN CLIMB TREES.
- (2) A HEDGEHOG IS A PRICKLY ANIMAL.
- (3) ALL PRICKLY ANIMALS CAN ONLY MOVE SLOWLY.

Therefore:

- (1) All animals that can only move slowly are prickly.
- (2) A hedgehog has no need to climb trees because it can curl into a prickly ball.
- (3) All animals that can move quickly can climb trees.
- (4) A hedgehog can move quite fast sometimes.
- (5) No hedgehogs can climb trees.

Problem N is a piece of deduction of a more elaborate nature than either L or M. The premisses are not presented in an order which leads readily to the conclusion and they are not stated in hypothetical or conditional form, a fact which might be expected to make the common-sense distractors more powerfully alluring than in the two preceding problems, and which did indeed appear to have this effect.

Distractors (2) and (4) belong very clearly to the common-sense class. Distractors (1) and (3) are logical fallacies.

The correct solution does accord with real experience - to the best of the writer's belief! - and so it is very important to try to ascertain whether it is or is not reached deductively. Indeed, on the whole, this problem departs from experience much less obviously than do L and M, and common-sense reasons were frequently given for acceptance and rejection of all distractors and of the correct solution. Nine

children chose common-sense distractors (eight - distractor (2); one - distractor (4)), four chose logical fallacies; seven chose the correct solution. But full genuine deduction seemed to occur in only three cases.

Here are a few quotations:-

Ian (K1): "It can't be (3) because a lion moves fast but it can't climb trees."

Linda (M4): "It might be (5). (Why?) Because they're fat and they have small feet and couldn't cling to trees. Or maybe (4), because no one has real proof they don't move fast sometimes."

Pat (K5): "Well, it's not (1), because a snail moves slowly and it's not prickly."

Many of the children were obviously quite satisfied with reasons of this kind. Some, however, seemed to be aware that they should be deducing - or "imagining it out of this" as one boy put it - even when they did not succeed in doing so. Thus:

Douglas (K4): "I think (5) is the most sensible. (Why?) Well, they can't really. But if you're imagining it out of this [pointing to premisses] I'd say (1). (Why?) Well, the hedgehog is very slow and it is prickly."

Elizabeth (M5): [Long pause] "Number (1). (Why?) Well, animals that can move slowly can't climb trees. (Why does it follow from this?) Well, a hedgehog is a prickly animal. [Pause] It might be number (4), because you need to be quite fast to climb a tree."

A few children gave quite explicit accounts of the fallacious reasoning which led them to choose (1) or (3).

Pat (M2): "Number (3). (Why?) If all animals that move slowly can't climb trees, then animals that move quickly can."

This would appear to be a very clear illustration of the kind of tendency which has already been referred to several times as "exclusion", or failure to deal with overlap. Here it is failure to take account of the possibility of overlap. S and P are seen as co-extensive not as possibly only partly so. The notion that S may lie wholly within some larger P is not considered.

Relevance was again sometimes taken as a criterion for acceptance or rejection of solutions.

Margaret (N1): "Number (2) won't do. It doesn't say anything about a hedgehog wanting to climb trees."

Pat (N2): "Number (3) - that's it, I think. But (5) is right as well. It tells you. [She then re-read premisses in order (1), (3), (2)] (Which do you choose, then - (3) or (5)?) It's (5). (Why?) Because it's not talking about the other animals, it's talking about the hedgehog."

This last is interesting, because the girl has apparently deduced the right solution yet is also willing to accept one of the fallacies. Her final reason for choice is also interesting. Does she in some way appreciate that "prickly animals" and "slow-moving animals" are middle terms and that the conclusion should be making a link between hedgehogs

and the ability to climb trees?

Finally here are two answers in full. The first is an example of perfect and unhesitating deduction (from a girl who was also correct in Problem M); the second is a good instance of self-correction, from a boy who, though very good at most of the problems, accepted logical fallacies confidently in L and M.

Margaret (N₃): "Number (5). (Why?) Because it says 'No animals' [reading first premiss] That means animals that move slowly can't climb trees, and it says prickly animals move slowly and the hedgehog is a prickly animal, so it can't climb trees."

Ian (N₄): "Number (1), I think. (2) and (4) have nothing to do with it at all, so they're out [scornful tone] (3) could be true. [Re-reads premisses carefully] I'm not so sure about (1) now. It just tells you well, there's more animals than prickly ones that can move slowly. I think it's (5) now. (Why?) Well, slow animals can't climb trees, and a hedgehog is a slow animal. (How do you know?) Because all prickly animals can only move slowly."

The scornful tone in which the common-sense distractors are dismissed is worthy of note. This was the only sign of such scorn.

Comparison of L and M with N reveals that almost all the children who chose common-sense distractors in L or M do so also in N. But some of those who kept strictly to logical fallacies in L and M succumb to the temptation of distractor (2) in N; and this is even

true of Morag (K6) who chose a logical fallacy in L and the correct answer in M. Without follow-up we are not, of course, in a position to say what is the predictive significance of the choice of one kind of distractor rather than another at this stage. This is a question that it would probably be very profitable to investigate.

- (3) A cat would probably be able to swim faster than a mouse.
- (4) A trout would probably be able to swim faster than a puppy.
- (5) It would not be possible for a cat to catch a fish.

This problem proved to be less fruitful than usual. Thirteen of the children could solve it fairly easily. There was an occasional wrong-answer branch for rejection of a distractor - for example:

Jan (11): "I think (4) isn't true. If a puppy was always kept in the water it would be more used to it."

William (11): "It's not (1) or (2), because a cat or bird wouldn't go underwater and a pig wouldn't be in the air."

The second of these examples is rejection of the whole "water-believe" while the first is not; but neither is drawn from the premises in any way.

One or two interesting reasons for acceptance of distractors were offered. For instance - Douglas (11) and Morag (10) - thought (1) could be considered true because "a puppy couldn't swim at all".

Occasionally distractors were accepted because of partial and inadequate application of premises, e.g.

"Number (1) could be true, for a bird could swim."

and questions of course the premises were quite corrected, though this

PROBLEM O:

IF BIRDS COULD SWIM BUT COULDN'T
FLY, AND ANIMALS COULD FLY BUT
COULDN'T SWIM, AND FISH COULD DO
BOTH

Then:

- (1) A cat might catch a bird under water.
- (2) A shark might catch a pig in the air.
- (3) A cat would probably be able to swim faster than a mouse.
- (4) A trout would probably be able to swim faster than a puppy.
- (5) It would not be possible for a cat to catch a fish.

This problem proved to be less fruitful than most. Thirteen of the children could solve it fairly easily. There was an occasional common-sense reason for rejection of a distractor - for example:

Ian (K1): "I think (4) isn't true. If a puppy was always kept in the water it would be more used to it."

William (L1): "It's not (1) or (2), because a cat or bird wouldn't go underwater and a pig wouldn't be in the air."

The second of these examples is rejection of the whole "make-believe" while the first is not; but neither is drawn from the premisses in any way.

One or two interesting reasons for acceptance of distractors were offered. Two children - Douglas (K4) and Morag (K6) - thought (4) could be considered true because "a puppy couldn't swim at all":

Occasionally distractors were accepted because of partial and inadequate application of premisses, e.g.

"Number (1) could be true, for a bird could swim."

And sometimes of course the premisses were quite confused, though this

was rarer than might have been expected.

Distractor (5) gave some difficulty because of the negative involved. Two children were tricked by it into acceptance of (5), and one or two saved themselves just in time.

For example, Carole (K3) says:

"Number (5) - that's right! If a fish was in the air at the same time it would be possible, so it's this one."

Once more a few children were prepared to accept several of the statements as true. The decision then seemed largely fortuitous. There was little chance for considerations of relevance to operate here - though one girl insisted that the right solution "went better" than (3) or (5), which she also accepted as true.

Only one girl began by stating the premisses more concisely, thus:

"Animals fly, fish do both, birds swim."

She was able to deal with the problem very efficiently, as might be expected.

CHAPTER VI.DISCUSSION OF RESULTS

In such a study as this it is impossible strictly to separate the statement of results and the discussion of them, and much that belongs under the heading of discussion is already contained in the preceding pages. The function of the final section must therefore be to draw together these earlier scattered discussions and summarise the conclusions and questions that emerge from the work as a whole. This purpose can perhaps best be served by a consideration of the errors that were found to recur most frequently in a variety of problems; and by an attempt to relate findings to the opinion expressed in Chapter III that the study of errors may be of direct service in the development of intelligence testing in three main ways.

The main recurrent errors were:

(1) Rigid separation of the "components" of a problem in such a way that no allowance is made for the possibility of overlap or inclusion of one within the other.

(2) Failure to handle asymmetrical relationships successfully and with understanding of the equivalence of different statements.

(3) Abandonment of reasoning at a point in a problem where there are two possibilities,¹ one of which must be rejected. This might be (a) more or less conscious; or (b) apparently unaccompanied by any awareness of an inadequacy of reasoning.

1. Notice that this was never observed to occur when more than two possibilities were open.

(4) Failure to reconsider a conclusion once reached, even if it led to evident contradiction.

The first two of these errors are of much interest in relation to Piaget's theories about the development of intelligence. In "La Psychologie de l'Intelligence" he describes an experiment conducted with six-year-old children. Twenty beads are placed in a box. All are made of wood. Most of them are brown, a few are white. With the beads in full view the child is asked: Are there more wooden ones or more brown ones? According to Piaget a child under seven will almost always reply that there are more brown ones "because there are only two or three white ones." He is then asked: Are the brown ones wooden? - Yes - If I take away all the wooden beads, will any beads be left? - No. - If I take away all the brown ones will any be left? - Yes, the white ones. Then the original question is repeated and the child still affirms that there are more brown beads than wooden ones.

The child who gives this reply is evidently unable to appreciate the inclusion of the class of brown beads within the class of wooden beads. Piaget's explanation is that he can focus his attention on the whole class (wooden beads) or on the two parts (brown beads and white beads), but that when he focusses on the parts he destroys the whole by that very action. This Piaget ascribes to a lack of mobility in the successive focussings.

The children in the present study are of course much older than those who were the subjects of this experiment of Piaget's. But Piaget's theory is that in general the same difficulties encountered in dealing with objects at the age of 6 or 7 recur at 11 or 12 when

words are substituted for objects. It is therefore interesting to see how his theory applies to the instances of "exclusion" or difficulty with overlap which were observed in this investigation.

Errors which seemed to be in some way connected with overlap difficulty occurred in Problems B, D, J, F to I, K, L, M and N.

In Problem B, there was trouble with overlapping series such as "AB, BC, CD" In D and J there was failure to recognise the inclusion of one interval of age or height within another. In F to I there was a tendency to arbitrary division into groups which suggested that the notion of a continuous series was not fully developed. (It is perhaps not obvious that this is an error of the same sort as the others, but there are grounds for suspecting that it is closely connected. There is the same rigidity of separation of components.) In K there was failure to recognise the "I" as one of the group of brothers. In L, M and N, choice of a logical fallacy distractor amounted to failure to recognise the possibility that one class might be wholly within some larger one.

Common to these errors seems to be a tendency to see all things as self-contained, in such a way that if D belongs in the group "CD" it cannot at the same time belong in the group "DE"; the three-year interval cannot be part of the five-year one; an object must be either "big" or "small" and cannot at the same time be big in relation to certain objects and small in relation to others; "I" am not seen as "my brother's brother"; and if all boys who have red hair are known to play football well then these two classes are co-extensive and it is inconceivable that some members of the class of boys who play football well should have brown hair.

The error, then, lies not in a failure to perceive inconsistencies (which might have been expected) but rather in a failure to perceive consistencies. There is failure to recognise that given statements of relationship do not necessarily preclude all other statements of relationship involving the same objects

If this is so, then the second recurrent error appears to have much in common with the first, for there thought is set in one posture in a very similar way. Considerable mental agility is necessary for the realisation that "Tom is older than James" and "James is younger than Tom" are statements of the same relationship, and it is precisely this agility, this ease of transition, which seems to be lacking. This agrees very closely with Piaget's findings.

The third error in the list should perhaps really be regarded as two quite separate errors, because the distinction between more or less conscious guessing and real unawareness of any inadequacy in reasoning is probably a very important one. When there is real unawareness it is as if the child has no sense of "either A or B" as a statement of uncertainty that must be resolved by proof, but is regarding the "or" as implying that choice is appropriate and that he has powers of allocation. This last suggestion is offered very tentatively because it was considered as a possible interpretation only after the experimental work had been concluded and it has therefore not been tested in any way. But if it is correct, then the question raised in discussion of Problem E about the development

of the concept of proof at this age may have some bearing on this error; and there may also be some connection with the errors that consisted in choosing "common-sense" distractors in the syllogistic problems.

On the other hand, when error (3) involves guessing that is recognised as such, there is this in common with error (4): it might be argued that neither is attributable to a failure of intellect in so strict a sense as are the other three. These two errors are due rather to a failure of effort and a willingness to be content with what is not regarded as satisfactory even in the moment of its acceptance. In some cases it seemed very much as though the inflexibility that showed itself in the clinging to a conclusion once reached was the result of a very real fear that reconstruction from the beginning would prove impossible and of a conviction, no doubt unconsidered, that it was better to hold on to a wrong solution than end by having no solution at all.

Inflexibility of one sort or another is, then, a very general feature of these errors; but it would be incautious to assume that the inflexibility of error (4), which is a failure to act on perceived inconsistencies, has any connection with the failures to perceive consistencies that have previously been discussed. Indeed at the moment it looks very much as though they may have quite different sources and show no tendency to occur together. What they have in common to justify the application of a common term is that both, in

different ways, involve the fixing or "setting" of a first impression into immutability.

The suggestions made in Chapter III will now be considered in turn in relation to the experimental findings. The first of these suggestions was that the study of errors might further the development of intelligence testing by increasing our understanding of the psychological relationships between different problems, and might throw doubt on the present practice of classifying items into "types" on the basis of obvious resemblances of form.

Relevant to this are the results of an inquiry conducted by Sir Godfrey Thomson in one of the few attempts that have been made to study intelligence test problems one by one in their prognostic capacity. Sir Godfrey made a careful follow-up study of the individual items of a Moray House Test and he reports¹ that he found reason for suspicion that the "type" of a question was by no means a sure index of its efficiency for selection purposes. Questions which looked very similar were found to differ greatly in the success with which they made the distinction between ability and inability to undertake a course of secondary school studies.

Sir Godfrey was inclined to regard the difference between successful and unsuccessful items as one of "difficulty", and this,

1. G. H. Thomson: Following-up individual items in a group intelligence test. Brit. J. Psychol., 1942, 32, 310-317.

in a sense, it no doubt is. But the findings of the present study make it seem clear that the reason why follow-up showed formal type to be a poor index of prognostic value¹ is that questions formally similar may differ very greatly in respect of the sorts of understanding and competence necessary for their solution, while those formally different may be in these respects closely akin. This study, although not yet related to any follow-up, shows repeatedly how questions that are, on superficial inspection, of the same type may in fact be solved incorrectly because of very different errors. Consider, as examples, the series AB, FG, KL... and the series AB, BC, CD... The first of these is particularly liable to provoke the error described as "miscounting" (see page 79) while the second demands competence in dealing with overlap (see page 79 and the preceding section of this discussion). The discovery of this difference makes it evident that these two questions may be of very different prognostic value, and this even if "difficulty", as measured by percentage correct, were found to be practically the same.

On the other hand, there are some apparently widely differing problems in which very similar sorts of error commonly occur. There is no need to illustrate this here, since the main recurrent errors have already been discussed at length. But it is relevant to the present topic to point out that this fact not only casts serious doubt on our practice of classifying by formal type in deciding, say, in what proportions a test will be composed, but also explains why

1. It is very easy to see how such a finding as this might seem to give support to the notion that it is not profitable to spend time trying to justify the choice of test items on any basis other than that of follow-up.

the giving of different weight to different formal types of question has generally seemed to make so little difference in the end to distributions of total score.

The second contribution to intelligence testing that we might look to the study of errors to make was said in Chapter III to be the augmenting of our ability to make direct inferences from final solutions to "underlying events", the advantage to be derived being, of course, that we might then assess a child's mental powers on the evidence of his written answers with more precision and confidence than are possible to us in the present state of our knowledge. This is a more ambitious suggestion than the first one; and the opinion that we can never make such inferences with perfect confidence has already been expressed. (See page 37) We may study five hundred children and find that in every case where a certain wrong solution is offered it seems to be due to the same defect in understanding. But we must recognise that it is never impossible for another child to come along and arrive at this same solution in a different way.

This reservation made, however, the work so far done would seem to give some indication of what it might be possible to achieve.

There are in fact two possibilities: to be content with classifying wrong solutions according to the errors which are found commonly to underlie them; or deliberately to construct questions so as to invite certain errors and render less probable the

occurrence of others. Now obviously if follow-up shows the occurrence of some kinds of error to be more significant than that of others, control of errors by deliberate question construction will be very desirable; for if the purpose of a question is to assess the child's freedom from or liability to a certain sort of error and he solves the question wrongly because of a different incompetence that purpose will not have been served. Ways of exercising this control are therefore important to consider; and the most obvious is by informed choice of exact wording and manner of presentation; though again there is a reservation to make, because it is of great importance to remember that children are active in the interpretation of problems, and however skilfully they are constructed we can never be sure that each child will be affected by variations in the same way. This, however, does not make it unimportant to have knowledge of the most common effects of certain sorts of change. To investigate these fully, numerous comparative studies¹ would have to be undertaken; but the results of the present study provide some suggestions of the kind of difference which it might be important to consider. For instance, the premisses of Problems L and M were stated in hypothetical or conditional form, while those of Problem N were stated categorically, and it has already been suggested (page 119) that this may have had the effect of making the common-sense distractors in the latter problem particularly attractive. Again, in Problem A the possible importance of using names which readily form a set was mentioned (page 69);

1. Burt (J. Exp. Ped., 1919, 5, 121-127) considers the effects of changes in wording and finds them to be considerable.

and the significance of the wording of the negative statement "Tom has never been inside Central School" was considered on pages 72 and 73. The footnote to page 93 has suggested that in Problem D the statement "May is older than Jean" may have, in its context, an effect different from that of the statement "Jean is younger than May"; just as, in Problem J, the substitution of "Tom is smaller than Harry" for "Harry is taller than Tom" might make errors of asymmetry less likely to occur by firmly associating Tom with the smaller end of the scale. Further, in both D and J, the effect of syntactical changes might be considerable. In each case the relationships on which the problem mainly depends are stated in a rather long and involved sentence. If two or even three sentences had been used to give the same information, so that there was less risk of losing sight of the grammatical subject, some of the overlap errors might not have occurred. This possibility was mentioned on page 100.

There is, then, a strong case to be made for the study of the effects of quite small changes in the wording and the syntax of problems. But there is another possible way of controlling the occurrence of errors which would seem at first sight both easier and more likely to be effective, and that is by the use of the "multiple-choice" form of question and the judicious selection of distractors. Thus it might be argued that in Problem J the inclusion of "Harry is 5ft. 10ins. tall" and "Tom is 5ft. 6ins. tall" as possible choices would make the problem more effective as a test of ability to handle asymmetrical

relationships than it is at present; and similarly that it would be possible to construct a set of distractors specially designed to invite errors involving inability to deal with overlap. Thus these different errors could be isolated and the extent of the child's liability to each of them could be separately assessed. There are, however, a number of important objections to this procedure. It has already been acknowledged that even though we discover that a given error leads almost infallibly to a given wrong solution we can never make a completely confident inference from the solution back to the error. We can do it much more confidently, though, if the solution has been freely produced by the child than if it has been chosen by him from a restricted list. There is evidence in the results that children are sometimes actually prevented by multiple-choice solutions from structuring a problem effectively at all. Instead, they work through the list accepting or rejecting the choices for reasons that are not always integrated with one another; and all manner of confusions and possibilities of contradiction may arise. The answer given by Pat, (M2) to Problem J, and quoted on page 102 is a good example of this and shows how, if one were to choose distractors with the object of inviting errors of overlap and asymmetry, the occurrence of muddles and contradictions could defeat this aim by becoming hopelessly interwoven with the errors at which the question was aimed. To put this in other words, multiple-choice solutions are

likely to fail to make important distinctions because of the existence of a group of errors which produce no characteristic wrong solutions, but may manifest themselves in an unlimited number of ways.

It will be recalled that when the main recurrent errors were discussed there were found to be grounds for suggesting a distinction between errors (1), (2) and (3b) on the one hand and (3a) and (4) on the other (see page 130). This distinction is now relevant because it seems to correspond to some extent to the distinction between errors which lead regularly to a small number of predictable wrong solutions and those whose effects on the solution finally offered cannot be foreseen. Thus the effects of errors (1) and (2) can be anticipated quite readily once the error is known; but those of (3) and (4) are much harder to predict because of the manifold opportunities for reasoning to give rise to possibilities of contradiction or to points of decision between alternatives.¹

To attempt another and more general statement of the difference, it would appear that errors (1) and (2) are failures of reasoning; while errors (3) and (4) - or at least (3b) and (4) - are failures to reason.

1. The status of (3a) is puzzling because it would seem to belong in this respect with (3b) and (4) rather than with (1) and (2), although in the previous discussion it was classed with the latter. But little is known about it and it is in many ways the most perplexing of the errors observed.

If one then considers the application of this distinction to the less frequently recurring¹ errors it becomes clear that some - for instance, failure to use one's own solutions to solve later parts of a problem - are failures to reason; some - for instance, difficulty with negative statements - are failures of reasoning; and some cannot readily be assigned to one class or the other. This difficulty in classifying may arise because understanding of the errors is incomplete; but more probably it arises because the classification is not all-inclusive. That an important distinction exists does, however, seem clear; and, for the present, I propose to refer to errors that are failures of reasoning as "conceptual errors"; and to those that are failures to reason as "non-conceptual errors" in order to avoid premature assumptions regarding their nature and source. It is evident, then, that the making of inferences from wrong solutions to errors is rendered much more difficult by the existence of the non-conceptual errors, because they are much harder to test - and much harder to avoid testing. At the same time, the results of this study show that some problems - when attempted by children of this age and ability, it is important to add - are in fact much more free of them than others. At one extreme is Problem K where the only error that occurs is very clearly of a conceptual kind. At the other are Problems A and C, where non-conceptual errors abound. Indeed, in

1. Frequency of recurrence is, of course, to some extent a function of the arbitrary choice of the interview problems.

these problems no error occurs that can confidently be classed as conceptual. It seems that the children have already passed beyond the stage of being in any doubt about the processes of identification by comparison on which solution depends; but in following the chains of reasoning that are involved they find very many opportunities for errors of a non-conceptual kind.

The question of whether it is possible to test the two sorts of error separately is, of course, unimportant in practice however it might be in theory, unless there are grounds for thinking it desirable. And the question of whether it is desirable leads directly to consideration of the third suggestion made in Chapter III: that the study of errors might contribute to resolution of the problem of providing theoretical justification for the inclusion in intelligence tests of some sorts of question rather than others. The way in which this contribution might be made was discussed on page 38 and it is to the argument advanced there that reference must now be made. To recapitulate briefly, it was there suggested that the study of errors might help to reveal the existence of "critical points" in a developmental sequence; and that the recurrence of one error in a variety of different tasks might be taken as indicating the likelihood that a critical point had been found. We have now to ask, then, whether, in the main recurrent errors that were together responsible for so many of the wrong solutions offered, we have evidence of critical points of development which (providing

always that follow-up brings verification of their critical nature) would provide a basis for the construction of test items for use at this age.

As soon as the question is asked it becomes evident that the distinction between conceptual and non-conceptual errors is relevant. The nature of the conceptual errors - so far as here observed - would seem to be fully compatible with the notion that they are the outcome of ways of mental functioning that hold a place in a regular sequence and give way in time to others more flexible and highly organised; and this is strongly supported by their agreement with Piaget's findings. But the position with regard to the non-conceptual errors is much less clear. If they, too, have their place in some developmental sequence then it is evidently a different one; and, although views about its characteristics must at present be in the nature of speculation, it would seem probable that its stages would be less well defined, its transitions less sharp, and that the possibilities of early cessation or slowing down of development - or even of regression - would be greater.

The conclusion to which this argument leads, then, is that the differences between the failures of reasoning and the failures to reason are such that attempts should be made to assess their occurrence separately, for purposes both of prediction and of finding ways of helping children to overcome them. Whether we choose to call them both failures of intelligence or to reserve this name for the failures of reasoning alone is unimportant. What is important is that the existence of a distinction between them should be recognised, that the existence of similar distinctions involving other categories of error should be explored, and that further study should be directed to their nature and significance.

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APPENDIX

The [illegible]

and [illegible] by the following [illegible] [illegible]
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APPENDIX

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APPENDIXThe Group Tests

Each test was prefaced by the following instructions, which are those regularly used in the Moray House Tests.

Read the following carefully:-

1. When you are told to begin, answer the questions as quickly and as carefully as you can.
2. Begin at the beginning and go straight through.
3. If after trying a question you find you cannot answer it, don't lose time but go on to the next.
4. When you finish one page, go on to the next.
5. You may do any rough working at the side of the page if you wish.
6. Make any alterations in your answers clearly.
7. Ask no questions at all.

Test I. (Alphabet).

The alphabet is printed here to help you with some of the questions.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Write your answers to these questions in the brackets.

1. If the letters of the alphabet from B to F were written in the opposite order beginning with F, which letter would remain in the same place as before? ()
2. Which letter is as many letters after K in the alphabet as C is after A? ()
3. Which letter comes between O and T in the alphabet but is not next to Q? ()
4. If the letters of the alphabet from M to S were written in the opposite order, beginning with S, which letter would remain in the same place as before? ()
5. If the letters in the word SPECIAL were rearranged so as to be in alphabetical order, which letter would then be in the middle? ()
6. Which letter in the word RESUMPTION occurs latest in the alphabet? ()
7. If the letters D and G were removed from the alphabet, which would be the sixth letter of those remaining? ()
8. Write the letter which comes midway between E and K in the alphabet? ()
9. If the alphabet had only twenty-four letters, E and H being left out, which would then be the tenth letter? ()
10. Which letter is as many letters before V in the alphabet as E is before G? ()
11. Write the letter which is next to L, but not next to N in the alphabet? ()

12. If the letters of the word DISPLAY were arranged in alphabetical order, which would then be the middle letter? ()
13. Write that letter which comes between the twelfth and fourteenth letters of the alphabet. ()
14. Which two letters in the word DEVIATION come after P in the alphabet? ()
15. Write the letter which comes midway between A and I in the alphabet? ()
16. If the letter O were removed from the alphabet, which letter would then be midway between L and S? ()
17. Which letter in the word OVERWHELM occurs latest in the alphabet? ()
18. If the first thirteen letters of the alphabet were placed in order directly above the last thirteen, which letter would be directly below D? ()
19. If the letters of the word GROUPED were rearranged so as to be in alphabetical order, which letter would then be in the middle? ()
20. One day of the week begins with the letter which comes just before N in the alphabet. Write the third letter of this day. ()
21. If the letters of the word REMOVAL were rearranged so as to be in alphabetical order, which would then be the middle letter? ()
22. Write the letter which comes midway between B and H in the alphabet. ()
23. Which letters in the word IMPULSE come after R in the alphabet? ()
24. If all the letters of the word GIBE were removed from the alphabet, which would be the sixth letter of those remaining? ()

Test II. (Elimination).

Read this:-

Five men, whom we shall call A, B, C, D and E, each inhabit one floor of a five-storied house.

B lives two floors above A and one floor below D.

E lives one floor below A.

Now write in the brackets the answers to the following questions:-

1. Who lives on the bottom floor? ()
2. Who lives on the top floor? ()
3. Who lives one floor up? ()

Read this:-

Betty, Jane, Tom, Peter and George sit round a circular table.

Betty sits on Tom's right.

George sits between Betty and Jane.

Peter sits between Tom and Jane.

Now underline in the brackets the correct answer to each of the following questions.

4. Who sits between Peter and Betty? (Betty / Jane / Tom / Peter / George)
5. Who sits between Tom and George? (Betty / Jane / Tom / Peter / George)
6. Who sits between Peter and George? (Betty / Jane / Tom / Peter / George)

Read this:-

There are four boys, A, B, C and D who like tea and coffee.
 A takes both sugar and milk; B takes milk but no sugar.
 C takes neither sugar nor milk; D takes sugar but no milk.
 A and D have coffee for breakfast; B and C have tea.
 A and B have coffee at tea-time; C and D have tea.

Now write in the brackets the answer to each of the following questions.

7. Which boy has tea without sugar and milk at breakfast? ()
8. Which boy drinks tea both at breakfast and at tea-time? ()
9. Which boy does not drink tea at either meal? ()

Read this:-

Five men, whom we shall call A, B, C, D and E, live in five different towns. These towns, not in order, are London, Birmingham, Manchester, Newcastle and Edinburgh.

A does not live in either London, Birmingham or Newcastle.
 E lives in Manchester.
 B does not live in either Newcastle or Birmingham.
 C has never been to Newcastle.

Now underline in the brackets the correct answer to each of the following questions.

10. Where does A live? (London / Birmingham / Manchester / Newcastle / Edinburgh)
11. Where does B live? (London / Birmingham / Manchester / Newcastle / Edinburgh)
12. Where does D live? (London / Birmingham / Manchester / Newcastle / Edinburgh)

Read this:-

A, B, C, D and E are five girls.
 A and E are tall; the others are short.
 C, D and E swim; the others do not swim.
 A and C play tennis but not golf; the others play golf.

Now write the answer to each of the following questions in the brackets.

13. Which of the tall girls plays tennis? . . . ()
 14. Which of the short girls does not swim? . . . ()
 15. Which TWO girls play golf and swim? . . . ()

Read this:-

There are five girls, whom we shall call A, B, C, D, and E. Each of them has one or more favourite colours.

A likes yellow and pink.
 B likes blue and green.
 C likes yellow and blue.
 D likes red, blue and green.
 E likes pink.

Each girl wears a frock of a colour she likes and no two girls wear the same colour.

Now underline in the brackets the correct answer to each of the following questions.

16. What colour is A's frock? . . . (pink / yellow / blue / green / red)
 17. What colour is B's frock? . . . (pink / yellow / blue / green / red)
 18. What colour is D's frock? . . . (pink / yellow / blue / green / red)

Read this:-

There are five men, whom we shall call A, B, C, D and E.
 A, B and C wear hats, the others go bareheaded.
 B and D carry umbrellas, the others do not.
 A and E wear spectacles, the others do not.

Now write in the brackets the answers to the following questions:-

19. Which man wears spectacles but goes bareheaded? ()
20. Which man carries an umbrella, but does not wear a hat? ()
21. Which man neither wears spectacles nor carries an umbrella? ()

Read this:-

I have five friends who live in the village where I live, and whom we shall call A, B, C, D, and E.
 A and C are tall while the others are short.
 C and E have red hair, while the others have brown.
 B and C go to the city early every morning, and don't return till the evening; the others remain in the village all the time.
 I myself don't leave the village, but I often meet a friend in the street.

Now write the answer to each of the following questions in the brackets.

22. One evening I met a friend who was tall and had brown hair.
 Who was he? ()
23. One evening I met a friend who had just come off a train.
 He was short and had brown hair. Who was he? ()
24. One afternoon I met a friend who was short and had brown hair.
 Who was he? ()

Test III. (Analogies).

Look at this example:-

Hand is to Glove as Foot is to (clothes / boot / arm / body / finger).

"Boot" is underlined because a boot covers a foot in the same way as a glove covers a hand.

Here is another example:-

Boy is to Man as Girl is to (infant / niece / brother / parent / woman).

"Woman" is underlined because just as a boy grows into a man so does a girl grow into a woman.

Now underline in the brackets the correct answer to each of the following:-

1. Book is to Library as Food is to (bread / eat / drink / cook / larder / oven).
2. Add is to Plus as Subtract is to (divide / minus / arithmetic / multiply / sum / equal).
3. Hand is to Palm as Foot is to (leg / ankle / toe / sole / arm / heel).
4. Fire is to Heat as Lamp is to (flame / candle / see / light / soot / dark).
5. Bow is to Arrow as Rifle is to (shoot / trigger / bullet / barrel / archer / target).
6. House is to Chimney as Ship is to (engine / coal / funnel / sea / cabin / smoke).
7. Castle is to Tower as Church is to (cathedral / priest / pulpit / roof / spire / pillar).
8. Father is to Son as King is to (queen / prince / emperor / president / throne / crown).

9. House is to Window as Ship is to (cabin / funnel / porthole / sea/
/ deck / captain).
10. Birth is to Beginning as Death
is to (funeral / age / bury / life /
/ illness / end).
11. Gas is to Gasometer as Water is to (pipe / reservoir / steam / air/
/ kettle / stove).
12. Shilling is to Pound as
Hundredweight is to (stone / ton / penny / weigh/
/ ounce / hundred).
13. See is to Blind as Hear is to (noise / ear / silent / dumb/
/ smell / deaf).
14. Electricity is to Switch as
Water is to (pipe / steam / tap / kettle/
/ gas / fire).
15. Weep is to Sorrow as Laugh is to (smile / clown / joy / frown /
/ cry / surprise).
16. Good is to Better as Bad is to (evil / worse / best / less/
/ worst / improve).
17. Bird is to Feathers as Cat is to (mouse / claws / tail / milk/
/ paws / fur).
18. Shilling is to Penny as Foot is to (inch / yard / pound / mile/
/ furlong / acre).
19. Pound is to Four Shillings
as Half-crown is to (sixpence / shilling / penny/
/ florin / five shillings / ten shillings).
20. Hill is to Mountain as Wood is to (tree / meadow / thicket / forest/
/ river / valley).
21. Yes is to Allow as No is to (not / ask / please / perhaps/
/ forbid / none).
22. Ankle is to Toe as Wrist is to (arm / foot / elbow / knuckle/
/ leg / finger).
23. Vinegar is to Sour as Honey is to (sugar / comb / bee / sticky /
/ sweet / yellow).
24. Long is to Short as Stretch is to (elastic / pull / small /
/ expand / tight / compress).

Test IV. (Classification (Excl.)).

In each of the following questions there are TWO things which are like each other in some way but are different from the others in the question. You have to find these two and underline them.

Here is an example:-

Tree / ocean / blue / cloud / green.

"Blue" and "green" are both colours, and so we have underlined them.

Now do these. Find the TWO that are most like each other, but different from the others in the question, and underline them.

1. James / Joan / John / Anne / George.
2. Laugh / weep / talk / sing / speak.
3. Summer / January / Monday / Christmas / August.
4. Foot / pound / minute / inch / gallon.
5. Iron / glass / wood / ink / wool / cork.
6. Apple / potato / pear / chestnut / barley.
7. Letter / stamp / postman / postcard / address.
8. 4 / III / X / V / 7 / II.
9. Brave / good / heroic / cowardly / bad.
10. Chin / forehead / neck / beard / nose / moustache.
11. Lake / forest / mountain / road / field / hill.
12. Wheat / meat / carrots / barley / fruit.
13. Desk / pupil / teacher / student / blackboard.
14. 22 / 40 / 55 / 70 / 10 / 30.

15. House / roof / cottage / garden / brick.
16. King / general / doctor / bishop / lawyer / major.
17. Tie / hat / coat / socks / cap / collar.
18. Sentence / comma / noun / grammar / verb.
19. Sing / paint / dance / read / work / draw.
20. Undecided / have / choose / wish for / pick out.
21. Sarah / Bill / Margaret / Anne / Arthur.
22. Betty / George / Margaret / John / Helen.
23. Money / penny / stamp / bank / sixpence / purse.
24. Comb / toothpaste / mirror / hairbrush / towel.

Test V. (Alphabet Series)

Look at these letters:-

....., D, F, H,

F is the second letter in the alphabet after D, and H is the second letter after F. In the first blank space, therefore, we must write B, and in the second blank space we must write J. Thus:-

.....^B, D, F, H,^J

In the same way, in each of the next questions there is a rule which tells how one letter or group of letters is found from those coming before or after it. Find out what this rule is, and then write in each of the two blank spaces what should go there. Remember you have to fill in TWO blank spaces in each question.

The alphabet is printed here to help you.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

In these questions you have to write ONE letter in each blank space.

1. . . . H, K, N,,
2. . . . D, H, L,,
3., J, L, N, P,

In these questions you have to write TWO letters in each blank space.

4. . . . LK, JI, HG,,
5., GH, HI, IJ, JK,
6. . . . ZN, YM, XL,,

In these questions write ONE letter in each blank space.

7. . . . A, D, G,,
8. . . . H, G, F,,
9. . . . J, M, P,,

In these questions you have to write TWO letters in each blank space.

10. . . . LM, LN, LO, ,
 11. . . . ZY, YX, XW, ,
 12. , PQ, QR, RS, ST,

In these questions write ONE letter in each blank space.

13. . . . N, L, J, ,
 14. , E, D, C, B,
 15. , E, H, K, N,

In these questions write TWO letters in each blank space.

16. . . . FG, GH, HI, ,
 17. . . . AP, BQ, CR, ,
 18. . . . GG, II, KK, ,

In these questions write ONE letter in each blank space.

19. . . . H, I, J, ,
 20. . . . M, K, I, ,
 21. , N, L, J, H,

In the next three questions, write TWO letters in each blank space.

22. . . . PP, QQ, RR, ,
 23. . . . ZA, YB, XC, ,
 24. , HI, JK, LM, NO,

Test VI. (Classification (naming)).

Look at these words:-

Pansy / violet / rose / flower / lilac

Pansy, violet, rose and lilac are all flowers. "Flower" is thus the general word which describes the others, so we have underlined "flower" as the answer.

In the same way underline the general word in each of the following questions.

1. Mutton / beef / pork / lamb / veal / meat
2. Sand / chalk / mineral / clay / coal / rock
3. Cottage / building / church / school / shop / museum
4. Bus / wagon / vehicle / tramcar / motor-car / dray
5. Maize / wheat / oats / barley / rice / cereal
6. Major / captain / lieutenant / officer / colonel /
/ brigadier
7. Paraffin / coal / fuel / wood / coke / petrol
8. Pot / saucer / saucepan / utensil / rolling-pin / spoon
9. Burrow / nest / home / cottage / lair / kennel
10. Sight / hearing / sense / smell / taste / touch
11. Trumpeter / organist / musician / pianist / drummer /
/ violinist
12. Medicine / profession / law / engineering / teaching /
/ science
13. Water / milk / liquid / wine / lemonade / oil
14. Rake / saw / hammer / chisel / tool / hoe
15. Instrument / thermometer / barometer / compass /
/ microscope / telescope
16. Fry / stew / bake / cook / grill / roast
17. Palace / mansion / cottage / bungalow / dwelling / villa

Test VII (Writing)

- 18. Emotion / fear / anger / love / despair / hate
- 19. Tin / metal / steel / lead / aluminium / zinc
- 20. Oats / wheat / rye / grain / rice / barley
- 21. Bottle / box / bag / cask / container / pail
- 22. Trunk / suit-case / mail-bag / luggage /
/ packing-case / kit-bag
- 23. Fly / beetle / insect / ant / wasp / butterfly
- 24. Wardrobe / table / arm-chair / settee / bed /
/ furniture

Test VII. (Coding).

Below are five words in a secret code. They mean

WHILE, SMILE, WHALE, ALIVE, WHEAT

but not in that order. By comparing them, especially their beginnings and endings you can find the meaning of each. Write the meanings in the brackets.

- | | | | | | | |
|----|---|---|---|---|---|---------|
| 1. | Y | J | C | N | G | (_____) |
| 2. | U | O | K | N | G | (_____) |
| 3. | C | N | K | X | G | (_____) |
| 4. | Y | J | G | C | V | (_____) |
| 5. | Y | J | K | N | G | (_____) |

Now here are five more words in the same code as before. They mean

LEARN, DAILY, ANNOY, REACH, FUNNY

but not in that order. By comparing them you can find the meaning of each. Write the meanings in the brackets.

- | | | | | | | |
|-----|---|---|---|---|---|---------|
| 6. | C | P | P | Q | A | (_____) |
| 7. | H | W | P | P | A | (_____) |
| 8. | T | G | C | E | J | (_____) |
| 9. | N | G | C | T | P | (_____) |
| 10. | F | C | K | N | A | (_____) |

Here are five words in a different code. They mean

BROWN, CREAM, CLOWN, CHEER, CLEAN

but not in that order. Compare them, and write the meanings in the brackets.

- | | | | | | | |
|-----|---|---|---|---|---|-----------|
| 11. | A | J | C | Y | L | (_____) |
| 12. | Z | P | M | U | L | (_____) |
| 13. | A | P | C | Y | K | (_____) |
| 14. | A | J | M | U | L | (_____) |
| 15. | A | F | C | C | P | (_____) |

Here are five more words in the same code as the last five. They mean

EVENT, EARTH, TARTS, PARTS, EMITS

but not in that order. Compare them and write the meanings in the brackets.

- | | | | | | | |
|-----|---|---|---|---|---|-----------|
| 16. | R | Y | P | R | Q | (_____) |
| 17. | C | K | G | R | Q | (_____) |
| 18. | C | T | C | L | R | (_____) |
| 19. | C | Y | P | R | F | (_____) |
| 20. | N | Y | P | R | Q | (_____) |

Here are four words in a different code. They mean

FANCY, FAIRY, MONEY, MARRY

but not in that order. Compare them and write the meanings in the brackets.

21. N L M V B ()

22. U Z R I B ()

23. N Z I I B ()

24. U Z M X B ()

Test VIII. (Related Series).

Underline the correct answers in the brackets to each of the following questions.

1. If all large coins were worth more than smaller ones, which of the following coins would be worth most?
(a halfpenny/a sixpence/a shilling/a farthing/a penny)
2. If all fast-moving animals were smaller than slower-moving ones, which of the following would be largest?
(tortoise / hare / sheep / mouse / hippopotamus)
3. If all rough substances were darker in colour than all smoother ones, which of the following would be darkest?
(writing-paper / blotting-paper / sandpaper / brown paper / tissue paper)
4. If all big articles were worth more than smaller ones, which of the following would be worth least?
(a watch / a hat / a flower-pot / an umbrella / a clock)
5. If all small articles weighed more than larger ones, which of the following would be heaviest?
(a pencil / a pin / a book / a table / a chair)
6. If all dark-skinned animals moved more swiftly than lighter-skinned ones, which of the following would move most slowly?
(fox / panther / grizzly bear / polar bear / wolf)
7. If all shiny substances were worth more than duller ones, which of the following would be least valuable?
(rubber / coal / steel / diamond / silver)
8. If all tall boys weighed more than all smaller ones, which of the following would weigh most?
(Tom - 5 ft. 2 in. / Jack - 4 ft. 9 in. / Dick - 5 ft. 5 in. / David - 5 ft. / Jim - 4 ft. 7 in.)
9. If all large animals were worth less than smaller ones, which of the following would be most valuable?
(horse / cow / monkey / elephant / cat)

10. If all small creatures could travel faster than larger ones, which of the following could travel fastest?
(snail / greyhound / shark / eagle / fly)
11. If all soft substances were rougher than all hard substances, which of the following would be smoothest?
(wool / rubber / diamond / mud / glass)
12. If all light substances were worth more than heavier ones, which of the following would be most valuable?
(petrol / cork / air / water / cotton-wool)
13. If all hard substances were hotter than softer substances, which of the following would be the hottest?
(ice / steel / cotton-wool / wood / leather)
14. If all big objects were softer than all small ones which of the following would be the hardest?
(cannon-ball / tennis ball / golf ball / cricket-ball /
/football)
15. If all slow-moving creatures were worth more than faster-moving ones, which of the following would be the most valuable?
(worm / race-horse / sheep / dog / deer)
16. If all heavy things were smaller than lighter ones, which of the following would be largest?
(a pound of sugar / half a pound of tea / an ounce of butter /
/a stone of potatoes / two pounds of flour)
17. If all fast-moving creatures were larger than slower-moving ones, which of the following would be largest?
(cart-horse / greyhound / rhinoceros / rat / snail)
18. If all hard substances weighed more than softer ones, which of the following would be the lightest?
(aluminium / tin / clay / glass / wood)
19. If all light substances were worth more than darker ones, which of the following would be least valuable?
(diamond / copper / wood / coal / lead)

20. If all heavy articles were larger than lighter ones, which of the following would be the largest?
(a milk-jug / a tray-cloth / a cup / an iron / a wooden spoon)
21. If the highest marks in exams were always made by the least clever children, which of the following marks would be made by the most clever child?
(68 / 72 / 55 / 42 / 40)
22. If all smooth substances were hotter than all rough substances, which of the following would be hottest?
(stone / ice / earth / wood / coal)
23. If all fast-moving vehicles were larger than slower-moving ones, which of the following would be smallest?
(car / train / motor-bicycle / horse-drawn cart / lorry)
24. If all rough cloth were worth more than smooth cloth, which of the following would be the most valuable?
(velvet / silk / sackcloth / wool / cotton)