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INTELLECTUAL EVOLUTION FROM ADOLESCENCE TO ADULTHOOD

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We are relatively well informed about the important changes that take place in cognitive function and structure at adolescence. Such changes show how much this essential phase in ontogenic development concerns all aspects of mental and psychophysiological evolution and not only the more "instinctive", emotional and sociological aspects to which this period is often limited. In contrast, however, we know very little about the period which separates adolescence from adulthood and we feel that the Institution FONEME's decision to draw the attention of various research workers to this essential problem is extremely well founded.

In this paper we would first like to recall the principle characteristics of the intellectual changes that occur during the period from 12 to 15 years, as, in wishing to reduce the psychology of adolescence to the psychology of puberty, these characteristics are too frequently forgotten. We shall then refer to the more general problems that arise in the next period (15 to 20 years); on the one hand those dealing with the diversification of aptitudes and on the other hand those concerning the degree of generality of cognitive structures acquired between the age of 12 and 15 years and the problem of what happens to them later on.

I) *The structures of formal thought.*

Between birth and the age of 12 to 15 years intellectual structures grow slowly, forming stages in development. The order of succession of these stages has been shown to be extremely regular and comparable to the stages of an ontogenesis. The speed of development, however, can vary from one individual to another and also from one social environment to another: in other words, we may find some children who seem to advance more quickly than the children around them, or others who appear backwards, but this will not change the order of succession of the stages through which they pass. Thus, long before the appearance of language, all normal children pass through a number of stages which lead to the creation of a sensori-motor or practical intelligence. Sensori-motor intelligence can be characterised by certain "instrumental" behaviour patterns, i.e. the child learns to use an instrument as a means to reach an end; such patterns bear witness to the existence of a logic which is inherent to the coordination of the actions themselves.

Once language has been acquired and symbolical play and mental imagery developed, or in other words, the symbolic function (more generally known as the semiotic function), actions turn inwards and become representations, this supposes a reconstruction and a reorganisation on a new plane which will be that of representative thought. However the logic of this period remains incomplete until the child is 7 or 8 years old. These internal actions or representations are still preoperational and only later become "operational" if we take operations to mean actions that are entirely reversible (as adding and subtracting, or judging that the distance between AB is the same as the distance between BA, etc.). Due to the lack of reversibility, there is not yet any comprehension of the idea of transitivity ($A \leq C$, if $A \leq B$ and $B \leq C$) nor has the child acquired the concept of conservation (for a pre-

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operational child, if an object's shape changes, the quantity of matter and the weight of the object change also).

Between the age of 7 to 8 and 11 to 12 years a logic of reversible actions is constituted, characterised by the formation of a certain number of stable and coherent structures, for example: a classification system, and ordening system, the construction of natural numbers, the concept of measurement of lines and surfaces, projective relations (perspectives), certain general types of causality (transmission of movement through intermediaries), etc.

Several very general characteristics distinguish this logic from the logic that will be constituted during the preadolescence period (between 12 and 15 years). Firstly, these are "concrete" operations, that is to say, in using them the child still reasons in terms of objects (classes, relations, numbers, etc.) and not in terms of hypotheses that can be thought out before knowing whether they are true or false. Secondly, these operations, which involve sorting, establishing relations between or enumerating objects, always proceed by relating an element to its neighbouring element–they cannot yet link any term whatsoever to any other term, as would be the case in a combinatorial system: thus, when carrying out a classification, a child, capable of concrete reasoning, associates one term with the term it most resembles and there is no "natural" class that relates two very different objects. Thirdly, these operations have two types of reversibility that are not yet linked together (in the sense of being composed one with the other): the first type of reversibility is by inversion or negation, the result of this operation is an annulment, for example, $+A -A = 0$, or $+n -n = 0$; the second type of reversibility is by reciprocity and this characterises operations on relations, for example, if $A = B$ then $B = A$, or if A is to the left of B, then B is to the right of A, etc.

On the contrary from the age of 11/12 years to 14/15 years, a whole series of novelties highlight the arrival of a more complete logic, that will attain a state of equilibrium once the child reaches adolescence at about 14/15 years. We must, therefore, analyse this new logic in order to understand what might also happen between adolescence and adulthood.

The principle novelty of this period is the capacity to reason in terms of verbally stated hypotheses and no longer in terms of concrete objects and their manipulation. This is a decisive turning point because to reason hypothetically is to deduce the consequences that the hypotheses necessarily imply (independent of the intrinsic truth or falseness of the premises); this is the formal reasoning process and it provides the logical procedure used in these deductions with a power of demonstration which was not the case in the previous stages. From 7/8 years the child is capable of certain logical reasoning processes but only to the extent of applying them to concrete objects or events in the immediate present: in other words the operational reasoning process, at this level, is not yet sufficiently detached from its content, and is, therefore, subordinated to the contingencies of the real world. On the contrary, however, hypothetical reasoning implies the subordination of the real world to the realm of the possible, and consequently the linking of all possibilities to one another by necessary implications that not only encompass the real, but at the same time, go beyond it.

From the social point of view, there is also an important conquest. On the one hand, hypothetical reasoning changes the nature of discussion: a constructive and fecund discussion means that by using hypothesis we can adopt the point of view of the adversary (although not necessarily believing it) and draw the logical consequences it implies. In this way, we can judge its value after having verified the consequences. On the other hand, the individual who becomes capable of hypothetical reasoning, by this very fact, will interest himself in problems that go beyond his immediate field of experience. This can be seen with the adolescent whose capacity to understand and even construct theories will create for him an entry into the society and ideology of adults; this is often, of course, accompanied by a desire to change that society and, if necessary, (in his imagination) destroy the present one in order to elaborate better ones.

In the field of physics and particularly in what concerns the induction of certain elementary laws (many experiments have been carried out under the direction of B. lnhelder on this particular topic), the difference in attitude between children of 12/15 years, already capable of formal reasoning, and children of 7/10 years, still at the concrete level, is extremely noticeable. The 7/10 year old children when placed in an experimental situation (laws concerning the swing of a pendulum, factors involved in the flexibility of certain materials, problems of increasing acceleration on an inclined plane) act directly upon the material placed in front of them without trying to dissociate the factors involved. They simply try to classify or order what happened by looking at the results of the covariations. The formal level children, after various tries, stop experimenting with the material and begin to list all the possible hypotheses. It is only after having done this that they start to test them, trying progressively to dissociate the factors involved and study the effects of each one in turn – "all other factors remaining constant".

This type of experimental behaviour, directed by hypotheses which are based on more or less refined causal models, implies the elaboration of two new structures that we find constantly intervening in formal reasoning.

The first of these structures is a combinatorial system, an example of which is clearly seen in "the set of all subsets", $2n^2$ or simplex. We have, in fact, previously mentioned that the reasoning process of the child at the concrete level (7/10 years old) progresses by linking an element with a neighbouring one, and cannot relate any element whatsoever to any other. On the contrary it is this generalised combinatorial faculty (1 to 1, 2 to 2, 3 to 3, etc.) that becomes effective when the subject can reason in a hypothetical manner. In fact psychological research shows that between the ages of 12 and 15 years the preadolescent and adolescent start to carry out (independent of all school training) operations involving combinatorial analysis, permutation systems, etc. They cannot, of course, figure out the mathematical formulae but they discover experimentally exhaustive methods that involve these operations. We would mention that when a child is placed in an experimental situation where it is necessary to use combinatorial method (for example, given five bottles of colourless, odorless liquid, three of which combine to make a coloured liquid, the four is a reducing agent and the fifth is water), the child discovers quite easily the law after having tried all the possible ways of combining the liquids in this particular case.

This combinatorial property of thought constitutes an essential structure from the logical point of view. If on the one hand the elementary classification and order systems, observed between the ages of 7 and 10 years, do not constitute a combinatorial system, propositional logic on the other hand implies, for two propositions "p" and "q" and their negation, that we not only consider the four base associations (p and q, p and not q, not p and q, not p and not q) but also the 16 combinations that can be obtained by linking these base associations 1 to 1, 2 to 2, 3 to 3 (one link being all four base associations and the other being the empty set). In this way it can be seen that implication, disjunction and incompatibility are fundamental propositional operations that result from the combination of three of these base associations.

At the level of formal operations it is extremely interesting to see that this combinatorial property of thought not only shows itself to be effective in all experimental fields, but that the subject also becomes capable of combining propositions; it would, therefore, seem that propositional logic appears to be one of the essential conquests of formal thought. When in fact, the reasoning processes of children between 11/12 years and 14/15 years are analysed in detail it is easy to find the 16 operations or binary functions of a bivalent logic of propositions.

However, there is still more to formal thought: when we examine the way in which subjects use these 16 operations we can recognize numerous cases of the four-group which is isomorphic to the Klein group and which reveals itself in the following manner. Let us take, for example, the implication $p \supset q$, if this stays unchanged we can say it characterises the identical transformation, if this proposition is changed into its negation N (reversibility by negation or inversion) we obtain N = p and not q. The subject can change this same proposition into its reciprocal (reversibility by reciprocity) that is, $R = q \supset p$; and it is also possible to change the statement into its correlative C (or dual) namely, C = not p and q. Thus we obtain a commutative four-group such that CR = N, CN = R, RN = O and CRN = I. This group allows the subject to combine in one operation the negation and the reciprocal which was not possible at the level of concrete operations. An example of these transformations that occurs frequently is the comprehension of the relationship between action (I and N) and reaction (R and C) in physics experiments; or again, the understanding of the relationship between two reference systems, for example: a moving object can go forwards or backwards (I and N) on a board which itself can go forwards or backwards (R and C) in relation to an exterior reference system. Generally speaking the group structure intervenes when the subject understands the difference between the cancelling or undoing of an effect (N in relation to I) and the compensation of this effect by another variable (R and its negation C) which does not eliminate but neutralizes the effect.

In conclusion to this first part we can see that the adolescent's logic is a complex but coherent system that is relatively different from the logic of the child, and that constitutes the essence of the logic of cultured adults and even provides the basis for elementary forms of scientific thought.

II) *The problems of the passage from adolescent to adult thought.*

The experiments on which the above-mentioned results are based, were carried out with secondary school children aged 11 to 15 years, taken from the better schools in Geneva. However, recent research has shown that subjects from other types of schools or different social environments sometimes give results differing more or less from the norms indicated: for the same experiments it is as though these subjects had stayed at the concrete operational level of thinking.

Other information gathered about adults in Nancy and adolescents of different levels in New York has also shown that we cannot generalise to all subjects the conclusions of our research which were, perhaps, based on a privileged population. This does not mean that our observations have not been confirmed in many cases: they seem to be true for certain populations, but the main problem is to understand why there are exceptions and also whether these are real or apparent.

A first problem, is the speed of development, that is to say, the differences that can be observed in the rapidity of the temporal succession of the stages. We have distinguished four periods in the development of cognitive functions (see beginning of part 1) : the sensori-motor period before the appearance of language; the preoperational period which in Geneva seems, on the average, to extend from about 1½/2 years to 6/7 years; the period of concrete operations from 7/8 years to 11/12 years (according to research with children in Geneva and Paris) and the formal operations period from 11/12 years to 14/15 years as observed in the schools studied in Geneva. However, if the order of succession has shown itself to be constant –as each stage is necessary to the construction of the following one– the average age at which children go through each stage can vary considerably from one social environment to another, or from one country or even region within a country to another. In this way the Canadian psychologists in La Martinique have observed a systematic slowness in development; in Iran notable differences were found between children of the city of Teheran and young analphabetic children of the villages. In Italy, N. Peluffo has shown that there is a significant gap between children from regions of Southern Italy and those from the North; he has carried out some particularly interesting studies showing how children from Southern families immigrating North have counterbalanced these differences: similar comparative research is at present taking place in Indian reserves in North America, etc.

In general, a first possibility is to envisage a difference in speeds of development without any modification of the order of succession of the stages. These different speeds would be due to the quality and frequency of intellectual stimulation received from adults or obtained through the possibilities available to children for spontaneous activity which, of course, would be proper to the environment considered. In the case of poor stimulation and activity, it goes without saying that the development of the first three of the four periods mentioned above will be slowed down. When it comes to formal thought, we could ascertain that it will probably be extremely slow in constituting itself (for example, between 15 and 20 years and not 11 and 15 years); or that, perhaps in extremely disadvantageous conditions, such a type of thought will never really take shape or will only develop in those individuals who change their environment when development is still possible.

This does not mean that formal structures are exclusively the result of a process of social transmission, as we still have to consider what are the spontaneous and endogenous factors of construction proper to each normal subject. This signifies, however, that the formation and completion of cognitive structures require a whole series of exchanges and a stimulating environment; the formation of operations always gives rise to a favorable environment for cooperation, that is to say, operations carried out in common (the role of discussion, mutual criticism, problems raised as the result of exchanges of information, or extensive curiosity due to the cultural influence of a social group, etc.). Briefly, our first interpretation would mean that in principle all normal individuals are capable of reaching the level of formal structures, on the condition however, that the social environment and the acquired experience provide the subject with the cognitive elements and intellectual stimulation necessary for such a construction.

A second interpretation is possible which would take into account the diversification of aptitudes with age but this would mean excluding certain categories of normal individuals, even in favorable environments, from the possibility of attaining a formal level of thinking. It is a well known fact, however, that the aptitudes of individuals differenciate progressively with age. Bearing this in mind, a model of intellectual growth would be comparable to a hand fan open and erect, the concentric layers of which would represent the successive stages in development whereas the sectors, opening wider and wider towards the periphery, correspond to the growing differences in aptitude.

We would go so far as to say that certain behaviour patterns can be characterised by the way in which they form stages with very general properties: this occurs until a certain level in development; from this point onwards, however, individual aptitudes will become more important than these general characteristics and will create greater and greater differences between subjects. A good example of this type of development is the evolution of drawing. Until the stage at which the child can represent perspectives graphically, we observe a very general progress to the extent that the "draw a man" test, to quote a particular case as an example, can be used as a general test of mental development. On the contrary, however, if the drawings of 13/14 year old children were to be compared to the drawing of 19/20 year olds (this is sometimes done with recruits for the army) it is extremely surprising to observe the differences that separate individuals: the quality of the drawing no longer has anything to do with the level of intelligence. In this instance we have a good example of a behaviour pattern which is, first, subordinate to a general evolution in stages (cf. those described by Luquet and other authors for children from 2/3 years until about 8/9 years old) and which, afterwards, gradually becomes diversified according to criteria of individual aptitudes and no longer general development (i.e. common to all individuals). This same type of pattern occurs in several fields including certain which appear to be more of a cognitive nature. One example is provided by the representation of space which firstly depends on operational factors with the usual four intellectual stages – sensori-motor (cf. the practical group of displacements), preoperational, concrete operations (measure, perspectives, etc.) and formal operations. However, the construction of space also depends on figural factors (perception and mental imagery) which are partially subordinated to operational factors and which then become more and more differenciated as symbolical and representative mechanisms. The final result is that for space in general, as for drawing, we can distinguish a primary evolution characterised by the stages in the ordinary sense of the terms, and then a growing diversification with age due to the gradually differentiating aptitudes with regard to imaged representation and figural instruments. We know, for example, that there exist big differences between mathematicians in the way in which they define "geometrical intuition": Poincaré distinguished two types of mathematicians "the geometricians", who are more of a concrete nature, and the "algebristes" or "analystes", who are more of an abstract nature.

There are many other fields where we could also think along similar lines. It becomes possible, at a certain moment, for example, to distinguish between adolescents who, on the one hand, are more talented for physics or problems dealing with causality than for logic or mathematics and those who, on the other hand, show the opposite aptitude. We can see the same tendencies in questions concerning linguistics, literature, etc.

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We could, therefore, formulate the hypothesis that if the formal structures described in part do not appear in all children of 14/15 years and are, therefore, less general than the concrete structures of children from 7/10 years old, this could be due to the diversification of aptitudes with age. According to this interpretation, however, we would have to admit that only individuals talented from the logical-mathematical and physics point of view would manage to construct such formal structures whereas literary, artistic and practical individuals would be incapable of doing so. In this case it would not be a problem of underdevelopment compared to normal development but more simply a

growing diversification in individuals, the span of aptitudes being greater at 12/15 years, and above all between 15/20 years, than at 7 to 10 years. In other words, our fourth period cannot really be characterised as a stage, but would already seem to be an advancement in the direction of a specialisation.

But there is the possibility of a third hypothesis and, bearing in mind our present state of knowledge, this last interpretation seems the most probable as it allows us to reconcile the concept of stages with the idea of progressively differentiating aptitudes. In brief, our third hypothesis would state that all normal subjects attain the stage of formal thought if not between 11/12 to 14/15 years in any case between 15/20 years. However this type of thought will reveal itself in the different activities of the individual according to their aptitudes and their professional specialisations (advanced studies or different types of apprenticeship for the various trades); the way in which these formal structures are used, however, is not necessarily the same in all cases.

In our research to investigate formal structures we used rather specific types of experimental situations which were mainly of a physics and logical-mathematical nature as these seemed to be better understood by the school children we questioned. However, it is not out of the question that these situations are, fundamentally, very general and, therefore, applicable to any school or professional environment. Let us consider the example of carpenters, locksmiths, or mechanics who have shown sufficient aptitudes for successful integration into the trades they have chosen but whose general culture is not very extensive. It is highly likely that they will know how to reason in a hypothetical manner in their speciality, that is to say, dissociating variables involved, relating terms in a combinatorial manner and reasoning with propositions involving negations and reciprocities. They would, therefore, be capable of thinking formally in their particular field, whereas faced with our experimental situations, the lack of knowledge or the fact they have forgotten certain ideas that are particularly familiar to children still in school or college, would hinder them from reasoning in a formal way, and they would give the appearance of being at the concrete level. Let us also consider the example of young people studying law – in the field of juridicial concepts, and verbal discourse, their logic would be far superior to any form of logic they might use when faced with certain problems in the field of physics, involving notions they certainly once knew but have long since forgotten.

One of the essential characteristics of formal thought is that its form seems to be independent and detached from its reality content. At the concrete operational level, however, a structure cannot be generalised to different heterogeneous contents but remains attached to a system of objects or to the properties of these objects (thus the concept of weight only becomes logically structured after the development of the concept of matter, and the concept of physical volume after weight); a formal structure seems, therefore, to be more easily generalisable as it deals with hypotheses. However, it is one thing to dissociate the form from the content in a field which is of interest to the subject, and within which he will be able to show his curiosity and initiative, and it is another to be able to generalise this same spontaneity of research and comprehension to a field foreign to the subject's career and interests. To ask a future lawyer to reason on the Theory of Relativity, or to ask a student in physics to reason on the Code of Civil Rights is quite different to asking a child to generalise what he has discovered in the conservation of matter to a problem of the conservation of weight. In the latter instance it is the passage from one content to a different but comparable content, whereas, in the former, it is to go out of the subject's field of vital activities and enter a totally new field, completely foreign to his interests and projects. Briefly, we can retain the idea that formal operations liberate themselves from their physical content but on the condition we also add that this is true in situations involving "aptitudes similar to" or "vital interests comparable to" those already reflected by the subject.

III) *Conclusion*.

If we wish to draw a general conclusion from these reflections, we are obliged to say from the cognitive point of view, that the passage from adolescence to adulthood still raises a number of unresolved questions that need to be studied in greater detail.

The period from 15 to 20 years marks the beginning of professional specialisation and consequently also the construction of a life programme corresponding to the aptitudes of the individual. The vital question that we feel must be answered is to discover whether, at this level of development as at previous levels, there exist cognitive structures common to all individuals, which will, however, be applied or used differently by each person according to his particular activities.

The reply will probably be positive but this must be established by experimental methods that have been used in psychology and sociology. However, even if the reply is positive, the next essential step is to analyse all the probable processes of differenciation: that is to say whether, in the one instance, the same structures are sufficient for the organisation of many varying fields of activity but with differences in the way they are applied; or, in the other instance, there will appear new and special structures that still remain to be discovered and studied.

It is to the credit of the FONEME Institution to have realised the existence of these problems and to have understood their importance and complexity, particularly as, generally speaking, developmental psychology believed that its work was completed with the study of adolescence. Fortunately today certain research workers are conscious of these facts and we can hope to know more about this subject in the near future.

Unfortunately the study of young adults is much more difficult than the study of the young child as they are less creative, and already part of an organised society that not only limits them and slows them down but sometimes even rouses them to revolt. We know, however, that the study of the child and the adolescent can help us to understand the further development of the individual as an adult and that, in turn, the new research on young adults will retroactively throw light on what we already know about child development.

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