

Presentiamo qui uno scritto di Ceccato pubblicato nel 1966 come Report del Centro di Cibernetica e di Attività Linguistiche dell'Università di Milano di cui Ceccato era Direttore. Un testo interessante e non facile da reperire.

Brain Mechanisms of Learning: Psychological Approach^a

Silvio Ceccato^b

There is no doubt that it is easier for an anatomo-physiologist to become a cybernetician than for a psychologist; and it is even more difficult for a philosopher. Biological concepts are already naturalistic: biochemistry or, rather, biophysics leads directly to cybernetic models, which are not only of a mathematical or computer program type, but are, in fact, machines which may be built in accordance with certain chemical and physical features of the original. But, up to now, a good many psychological concepts and all philosophical concepts have always been incompatible with engineering techniques and also with the observations of the anatomo-physiologist.

Now, however, though the process of learning brings into play the mind, or, rather, the whole of our private mental life, the cybernetic psychologist must ask himself questions which must finish up on a naturalistic plane. What are the mechanisms operating in the learning being? Only by answering these questions is it possible to get an engineer to reproduce these mechanisms.

In any case, the designer of machines is at an advantage; in fact, he has two great advantages.

a) As he is the artificer of his creature, he can decide exactly what he wants to put into it, what is the potential capability of the machine when it is created, i.e., before it comes into operation. Therefore, he makes a precise distinction between what is "instinctive", "congenital", and what is "learned", and so on. With regard to the things which the machine does not do when it is first created, he is in a position to be aware of what the machine can do as a result of self-growth, and what must be attributed to something that it has been taught or directed to do. A very clear distinction comes into the field of learning, which is well-known in thermodynamics when we speak, for example, of entropy

b) The second advantage might be regarded as a, disadvantage by some psychologists and perhaps by all philosophers. It is this: the cybernetician cannot confine himself to speaking in general terms about these operations, be they primary, secondary, derived, learned, conditioned, and the like. Nor is it enough to define them as mental, psychic, or physical operations. Equally it is inadequate to refer to attitudes, adverse or favorable views, interest or disinterest, involvement or indifference, curiosity, the pleasure of reward or the displeasure of punishment, needs and their satisfaction, success or failure, etc.

There is no doubt that all these factors have an effect on learning. The cybernetician, however, is really on a bad wicket until he has pared down the learning process to modifications of organs. This pairing down involves the operational flow being minutely analysed into a kind of "atomic" operation, of operative atoms, which may be considered as functions of organs, and whose functioning, in its turn, must consist of changes in state, place, form, etc.. Before reaching this level of analysis it would be useless to think of constructing any machine. In any case, functions must be identified so as to be able to identify the organs themselves; and it is not enough for these functions to be defined in terms of means and ends on the basis of a kind of cybernetic over-simplification. The complexity that is required will be obtained later on by the combinations of these elemental operations.

Yet, it is only today that we are beginning to carry out this operational analysis. This kind of analysis has been prevented for hundreds of years by a number of very ancient presuppositions

^a "Brain Mechanisms of Learning: Psychological Approach", Centro di Cibernetica e di Attività Linguistiche, Università degli Studi di Milano, 1966, pp. 1-23. (the paper was scanned at OCR and reassembled like the original) - [Prepared for the *IVth International Congress of Cybernetic Medicine: 'Devices of Command and Control in Learning'*, Nice 19-22/9/1966]

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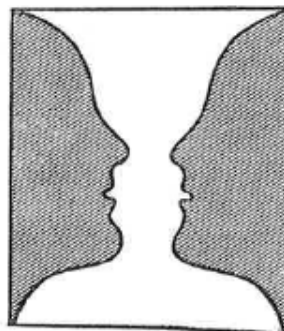
which have led to the human mind being considered as a collection of “abstract entities” rather than a series of operations. These “abstract entities” have no naturalistic sense as they cannot be conceived in terms of activities, in the sense that they are entities, nor can they be thought of as something physical, because they come about through an “abstraction”, which, in its definition, implies that the physical aspect has been removed from the scene. Some time will be required to complete the picture of operational analysis. Still more time will presumably elapse before we can proceed from the first essential step of these results to the actual identification, analysis and description of the organs which carry out, as their functions, the operations which will have come to light in the course of the analysis is.

It is difficult to think of learning, or even of self-growing, as other than a modification of the operating material. On the other hand, without this identification, analysis, and so on, it is clear that we must confine ourselves to noting certain regularities which, according to our findings, occur in some aspects of overt human behavior or in that behavior as a whole. In this behavioral study of man he will continue to be a “black box”.

I feel the best I can do in this *Congress* is to illustrate the results of operational analysis to date, stressing in particular the various functions performed by the attention and the memory in mental life.

With regard to models of organs capable of being imagined which may be responsible for the six functions of the memory and are fundamental to learning, we are all aware that our knowledge of the structure of living matter is totally insufficient to obtain an answer from biochemistry or biophysics. For the moment it is perhaps better to content ourselves with some partial solutions which may suggest what we should be looking for. For the moment perhaps it would be enough to associate the operations represented by a simple change in the state of one particular organ, for instance a photo-sensitive element, with the functions of the memory. We have chosen, as we shall show later on, a more complex system which enables us more easily to realize the way in which certain kinds of operation take on the different aspects allowed by the various functions of the memory: five resonators or strings and a sequence of notes.

I think that a small experiment is sufficient to show how man, when faced with a certain physical situation, has at his disposal quite a variety of responses. For instance, here is the well-known illustration which appears in every psychology text:

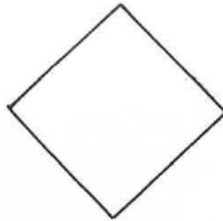


The pattern, the black and white, would always produce the same impression on a photographic plate; but we sometimes see a vase, and other times two heads in profile looking at each other.

Or else, here is some more black and white, which can be seen as a point, as a circle or as a little disc:



And thus, the following pattern, in which we can see a square, a particular case of rhombus, a parallelogram, and so forth:

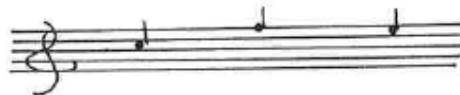


The photographic plate would always be affected in the same way by our same old black and white:



but we are ready to see either a proud Assyrian king or a modest little boot.

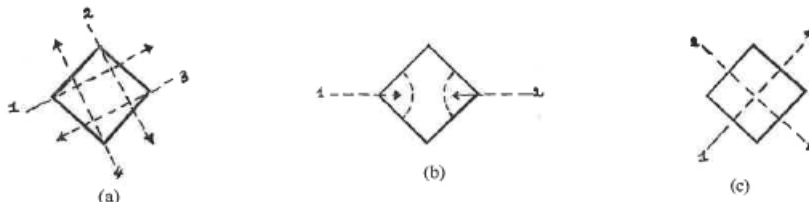
As to sounds, they too would always make the same impression on a tape recorder, but, for example, we might hear the three following:



once as three separate notes, C, F, and E, and another time as a theme.

Well, what does all this depend on?

Particularly in the case of the first illustration (Fig. 1), it is not difficult to understand it depends on the attention. It is a matter of directing the attention once to the black (an here are the two profiles) and once to the white (and we have the vase). In the case of the square, rhombus, etc., it is clear that the figure is analysed and then recomposed in different ways:



always in as much as we take up, in succession, different elements from them, and we take them up through attention, which works on the figure in different ways. We immediately find that in the case of the king, the attention moves to the left, and, in the case of the shoe, to the right.

Actually, the attentional mechanism has shown itself to be basic for the life of our brain. Our organism has its own dynamism which continues and which, even when all the attentional links are

cut and we are not aware of our body, continues to act in solidarity with the environment, through uninterrupted exchanges on the physical plane. We also know that of so much dynamism only a small part becomes conscious. But - and this is what is important to note and to keep in mind - that which has the possibility to become conscious, becomes conscious through the intervention of the attention.

We are certainly not the first to notice this fact Robert W. Doty, for instance, writes (in the report "Some Neural Facts Relevant to Attention" given for the course held at the International School of Physics, at Naples, in 1962): "We are unaware, for instance, of the pressure of our shoes, clothing, spectacles, the passage of air through the nose, saliva in the mouth, or of major portions of our visual or auditory environment unless 'attention' is specifically directed towards some aspect of these continuing sensory inputs." It is enough to change the last words, the "sensory inputs", and we can agree with Doty's assertions. There remains the fact that our body has a physical life, which could never become anything mental, but would run on, unconscious, if the attention did not intervene.

What is mental is attentional.

But the function of the attention does not consist alone in making present that which otherwise would remain absent for the mind, in making conscious what otherwise would run on unconsciously, and not even in its selective function on the functioning of our other organs. The attention operates also in the role of fragmentator of this functioning; it breaks it up, closing it in periods which last from a twentieth of a second to one or two seconds.

In this function of making present and fragmenting the functioning of other organs, the attentional mechanism reminds us of a phonograph. There we find in fact a system composed of the record which rotates (the functioning of the other organs), of the tone-arm with the needle (the attention which is applied or taken away): a system in which we can put in contact, at the place and the time wanted and for the desired duration, the two elements, through a combiner, which is usually our hand, or else, at the beginning or the end. of the record, an automatic device. The sound, or in our case, mental presence, thus depends on the coming into contact of the needle and the record, and the particular contents depends on the general contents of the record, on the point at which the needle has been placed, and on the time during which it has been left in contact.

Attention, however, is not applied to the functioning of other organs alone, but to itself as well. We possess it in fact both as pure, unfocussed, "empty" attention, that is, the state in which we are put if someone says "Watch out!", "Look!", or the like; and as attention which is filled by itself, which is focused on itself, according to a constructive passage, which can easily be followed if after the "Watch out!" someone says, for instance, "There it is!". In this case the first attentional state is not abandoned, but rather made to last until the second is added to it.

This possibility of holding on to something already done and adding something else to it, is among those which we most often utilize. It is enough to think of polyphony, or rather, to what happens to us if, when we have struck a piano key, without lifting our finger, we put another finger on top of the same key. In this case, although no other sound is produced, we realize that a second sound equal to the first one is added.

Nor do the combinational possibilities of attentional states end here; indeed, it is here that they begin. And in fact we find that we owe to them the entire world of the "logos", that is, of all the mental categories which we use daily whether in the pure state, or applying them to the functioning of the other organs with the result both of moulding that which is made present in various ways in many separate units, and of joining these units together.

As regards the combinations of attentional states, the variety of the constructions is given, once two of these states have been combined, by the possibility of using them as elements in a more complex combination - in which they are preceded or followed by a simple attentional state or also by combining two of these states, already combined, with two others, which are themselves already combined: a procedure which is, besides, already perfectly well-known in mathematics:

$$(a \times b) + c \quad a \times (b + c) \quad (a + b) \times (c + d)$$

But in the meantime, let us see what these first constructions are. The simplest of the combinations, that obtained from two states of attention, is nothing but that which is designated by the word "thing", in its broadest sense. And if, for instance, we rest our hand on a table-top and think of it - the table-top - as a thing, it is not difficult to realize that not only has it been made present, but the attention returns to it. Now, however, if we take it as an "object", the mental construction continues; that which is obtained by putting, in the combination, a simple state of attention before the category of thing, a situation in which the hand itself which rests on it might take part, producing the impression of finding it "against" the hand. The mental construction also continues if we think of the table-top as a "subject", this being obtained by making a simple state of attention follow the category of thing in the combination. The table-top itself could come to take part in this situation, producing the impression of "incorporating" it in us.

But certainly two other categories of which we make daily use can be more readily analysed: I refer to the categories of "singular" and "plural". The first is obtained if, in the combination, a state of simple attention is followed by the category of thing and this category is in turn followed by another state of simple attention; whereas the second is obtained if, in the combination, a category of thing is followed by a simple state of attention, which is in turn followed by another category of thing. The impressions produced, as can be easily checked, when these categories are applied, are: for the singular, that of isolating in a frame, that is, of remaining detached, then of participating, and then of remaining again detached; for the plural, that of breaking, or separating, that is, first of participating, then of becoming detached, and finally of participating again.

Let us check these impressions for example with the following figure, interpreting it first as a forest, that is, as singular, and then as trees, that is, as plural:



or when we hear a long train whistle, forcing ourselves to take it once as "a whistle" and another times as "whistles". This application is particularly revealing because it is in part exceptional, artificial.

By combining four states of attention, besides the singular, we obtain for example the two categories "beginning" and "end", the first obtained by making a state of simple attention precede the

category of object; and the second by making the state of simple attention follow the category of subject - as we can see if we categorize a pencil point in these two ways:



Two categories of fundamental importance in our life, constructed by combining categories which we have already mentioned, are those of space and time. The first results from making the category of plural follow the category of thing, and the second from making that of thing follow that of plural. Think for example about what happens when we propose to look at a thing, our hand, the room, etc., for instance, first in its spatial aspect and then in its temporal aspect.

What we have already begun to glimpse is that this world of the "logos" can be ordered according to the growing number of states of attention contained in the various categories and that even for categories composed of the same number of attentional states it is possible to establish an order of succession. This might not be immediately apparent if we give the various attentional structures, which we will call Y, a formal systematization according to the widely used notation of the Warsaw School:

- (1) Y is an S (where S represents a state of attention).
- (2) Y is a D_1SS (where D_1 represents the binary operator of which the S's are the arguments: operation D_1 consisting in maintaining a first state of attention when a second is added).
- (3) Y is a $D_2S D_1SS$ or a D_2D_1SSS (where D_2 represents the binary operator of which the arguments are a single S or a combination of S's: operation D_2 consisting of memorizing and taking up one S or a combination of S's).

But it is apparent even at first glance if the mental categories are arranged in a table and the groupings of capital S's are indicated with bars (in the Hilbertian manner).

I have here presented the first possible attentional constructions. As can be seen, not all of them have found employment and received a name, and larger blank spaces are found as we continue the series. The series although in theory it can be continued indefinitely, in practice (and this is easily understandable if we keep in mind our biological limits) end when the combinations reach a certain degree of complexity. Man, today, presumably after some hundred of thousands of years, has prepared himself a thousand or so mental categories of which, as we shall see, about two hundred are used as correlators in thought.

As to the functioning of the other organs which the attention makes present and break into fragments, a list of these elements as well would be indispensable in order to see with what stones the building of the mind has been constructed. These are in fact at the same level. In this regard I hold that we can be neither completely pessimistic nor completely optimistic. This list already exists more or less, even if it is rather imprecise and oscillating, when one gathers together, in dictionaries for example, the names both of colours, flavours, odours, etc., that is, of so-called sensory data, and those of the types of lines and surfaces into which various figures can be broken down, and which correspond to our movements. But this is certainly not a matter of values which

can be considered as minima, nor would it be useful for man to have individualized and named all of them for his daily uses. In order to ensure that the picture be complete, another path has been chosen, that of seeking to pair up these elements with physical situations according to the stimulus-response relationship, introducing units of measure into the study of physical situations of stimulus, and therefore introducing the order of the numeric series; whereas forms are treated by analytic geometry.

However, I think that a study of the thresholds whether absolute or differential in order to obtain an all-embracing picture of these elements, of these building blocks of the mental edifice, given our biological limitations, is not at all to be excluded. It can happen, of course, that the individual only uses a part of them.

What I now propose to show is the hook-up between|:a the results of attention - whether applied to itself or to the functioning of other organs - the physical and psychological world. This time the hook-up is no longer obtained through the stimulus-response relationship, that is, of physical *evocation* of mental or physical responses, but through the relationship, fundamental for our purpose, of the *constitution* of the psychological and of the physical on the part of the mental, a relationship which, in a certain respect, is inverse to the former.

(Note that here too it is not a matter of an articulation of the physical or psychological thing into other physical or psychological things, that is, for instance, the articulation which takes place when water is decomposed into hydrogen and oxygen, or jealously into fear and desire, when the elements and the whole retain the same spatial and temporal characteristics.)

Meanwhile, it will have been noted that the results obtained from the application of the attention to the functioning of the other organs can have, as such, neither moment nor place, in that this would require that they had first put into spatial or temporal relationship with something else, and therefore that the attention had been applied at least twice, in order to obtain this "something else", giving rise to two results kept distinct and then placed in that relationship. We are, that is, still at a simpler stage. If someone says "heat" or "cold", he has not yet said "heat now" or "heat here", contrasting it with a heat before or after or there, etc., just as, furthermore, he does not yet refer it to himself, as a "sensation", nor to something else as a "property". This is possible, but it has not yet come about, that is, the person has not yet operated in such a way as to localize it in time or in space, or in such a way as to add to it the mental category of subject or of (substance-) accident.

As the first operational "enrichment" of that which the attention has made present, we have, rather, the mental category of object. And these are the first results of its application. When it is made to precede in the constitutive order, we obtain the representation of the thing which has been made present, and when this category is made to follow, we obtain the perception of the thing. Thus, although in both cases the category, with its asymmetrical structure (of state of simple attention followed by the category of thing), whether isolating or objectifying, in the first case, in the representation, the isolation comes about only on the attentional level, in the second, it comes about on the level of the functioning itself, so that two things will be present, of which one is left and the other is held: the perceived thing too, though always arising as one of a pair, at the end remains alone.

As the second operational step, let us add the temporal or spatial localization of the represented thing or of the perceived thing. We obtain the possibility of pairing with these, respectively, another represented or perceived thing in a temporal or spatial relationship, provided that the representative or perceptive operating be repeated - a pairing which under a temporal aspect will give rise to a succession and under a spatial aspect to the presence of both together.

We have thus operated enough to reach the psychical and the physical; the first in that objectifying has been performed at least twice, temporally localizing the results and putting them into relationship with each other; the second because the results put in relationship with each other have been localized spatially. One should not expect to find those results of objectifying operation always taken as two distinct things, in as much as it is possible to link them respectively with duration and with extension, that is to consider them as the same thing. (And then when time is added to the physical thing, it is possible to see in the two things a state or a process, a subject or an object with its history, an "event", as when we speak of the water which boils or of boiling the water; just as, on the contrary, when space is added to the psychical thing, the psychical "event" can multiply itself, and, for example, a pain can be felt here and there, in the temples and in the eyes, etc.)

In any case, when more than one physical or psychical construction is put into play, the relationships which they have between them will no longer be our mental history, but theirs.

Let me illustrate this situation with an example: the moon. It is present to us under two quite distinct aspects: as a complex of elements each of which is not per se physical, that is, a certain color, a certain form, etc., in that these are the results of the functioning of certain organs which has been simply made present and fragmented by the attention; and as the moon which, following double representation or perception, stays still or moves, is higher or lower on the horizon, illuminates the earth at night, causes the tides, etc. In this case, the "richer" double operating has made a physical thing of it, with relationships of its own, its own history, and that of the earth, of the sea and so on.

Mental categories too, naturally, are found in relationship to each other, through the attentional states which constitute them; for example, in the category of "whole" we have as combined elements, the category of "beginning" and the "end". But they do not have history of their own; that instead pertains only to psychical and physical things, because they are localized in time and in space, and can be active and passive with respect to one another. Three apples can do many things; fall, be gathered, nourish, etc. etc.; but the number three cannot; it is completely "inert", in this respect, as a mental category, unable hence to become a two or a four.

After having been present at the birth not only of mental categories, but also of psychical and physical things through the combination of mental elements, one can now understand what the basis of my aspiration is: psychical and physical things too could be systematized according to a combinational serial order.

Even if no one perhaps may want this immense map, which the various individual disciplines could enlarge day by day, what we are here interested in showing, what I think is useful to be aware of, is the "mappability" of all these elements; so that each new piece, each new construction could always find its place in this combinational serial order, which furthermore would always be ready to furnish the new construction a classification and definition in mental terms.

What however will be the complexity of the contents of the most advanced pieces in the series. In this regard, I think we need not worry, provided that we do not confuse the operating present in the single pieces with the operating required by going through the entire map, at least until reaching the particular piece in the series (this is the error of whoever thinks that when we put two things, a tree and a cypress for example, into the relationship of genus and species, all the operations constitutive of tree are repeated for cypress, although it is easy to realize that, if for tree trunk, branches and roots are essential, these latter at least are not required for cypress). No single construction, whether mental, psychical or physical, is obtained with an operating which lasts longer than one or two seconds.

In order to constitute larger units, we have recourse to a different procedure, which gives us the

most ambitious human possession, thought.

Let us pause for a moment to consider the various functions which memory performs. It can keep present that which has just barely been done (that is, memory as the continuation of presence, such as eidetic images); it can again make present that which has been absent (that is, memory as retrieval). Then, it operates on the past not only passively, but also selectively and through association (that is, memory as elaboration, as creation), but above all, it operates on the past by condensing it, by summarizing it. Furthermore, it makes a propulsive force of it, it makes it act on the operating under way. Finally, memory can make present not only that which has already been made present by the attention, but also, although to a lesser degree, the operating of organs which has passed unnoticed. In this way, memory and attention complement each other, and the attention has before it a field which from the simple present is broadened to include our whole life.

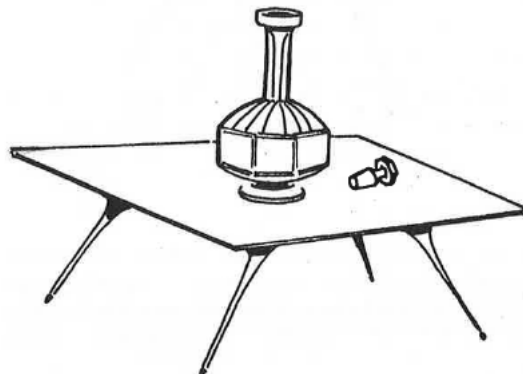
Well, in the constitution of single things, categories, or single objects, memory operates principally in its function of maintaining presence, that is, according to an essentially summative modulus; and it is for this reason that the constitution of the single category, the psychical or physical thing, does not exceed one or two seconds.

But memory, as we have seen, also operates as a condenser, a summarizer of that which has been done, and thus it permits structures of a new type, which can be indefinitely enlarged, a type to which thought itself belongs.

A description of thought can be begun by remembering that with the attention we break the operational flow of our organs, and with some mental categories we give a limit to the fragments already obtained with the category of object, etc. With other mental categories, and hence always with an attentional play, we can also however insert any other construction in the terms of a relationship, which both separates and unites. Furthermore, if this operating had not been imposed on us by our biological constitution, no solution would have been better prepared in order that the operating of the mind might be accompanied by language.

The principle of breaking the operational flow into pieces, but leaving the possibility of rejoining them, allows in fact every situation, no matter how complex, to be decomposed into a relatively small number of elements, and thus to obtain (by composing elements) a situation, no matter how complex; and the connections which must be fixed and transmitted, taught and learned, between symbols and symbolized things, that is, semantic connections, must not exceed this relatively small number, with the addition, as will be seen, of the indication of the places assigned to the terms of the relationship - a patrimony of connections of which man comes into complete possession more or less in a thirty-fifth of his life.

There are some very elementary examples of this procedure of separation and union, with their linguistic designations. Let us observe the following figure:

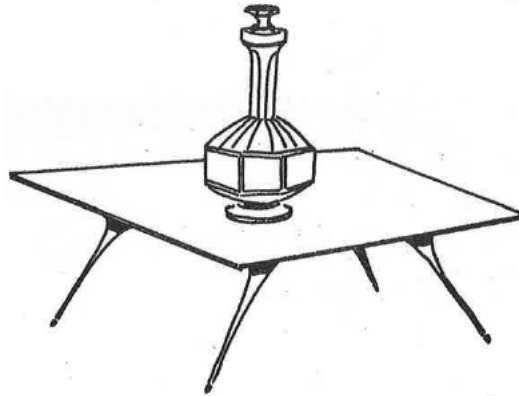


I believe that in no language could one find a word to indicate the table, the bottle, and the stopper all together, in as much as not even the possibility of seeing all this at one glance is given. But this is our happy solution to the problem: we break the observation up into three perceived things, fixing certain relationships between them: that of "and" between the bottle and the stopper, for instance, and that of "on" between these and the table. Thus we may say: "A bottle and a stopper on a table".

If we then examine this "and" we find that with a certain play the attention, although it has separated the two terms of the relationship, has not detached itself from the one to go to the other, thus giving rise to a structure which looks like this in the proposed system of writing:

SSSSSSSS

Thus, that "and" also indicates not only that the bottle and the stopper have been present one after the other, but also that a small interval has been put between them. If in fact the figure had been the following:



then the relationship between the bottle and the stopper would have been that of "with"- "A bottle with stopper on a table" - where the "with" indicates that the bottle and stopper have first been present together, without an interval, and have only subsequently been detached, whence the structure:

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Lastly, if, after the breaking up of the observation into the three perceived things, the attention, in going to the stopper from the bottle, had detached itself, the relationship placed between the two would be that of "or", in the formula:

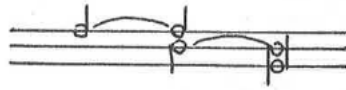
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(From the succession of the two ways of operating, it will have been noticed furthermore that mental categories, that is, attentional plays, are evoked by the peculiarities of physical situations, as furthermore they can evoke not only the processes of observation, but also our transformative operating itself, of our hands and so forth, as its intentionality; dependencies which however have usually been confused, by identifying the categories with the characteristics of the evoking or evoked physical situation, as for instance in the *Gestalttheorie*).

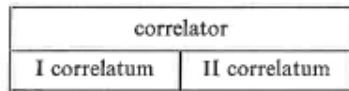
This then is thought: a placing of relationships, an opening and closing of relationships, a separating and joining of typically attentional stamp.

These triads, which constitute thought, have a characteristic dynamism, in that the first term, or first correlatum, is the first in time to be constituted, and is then held until it is present along with the mental category of relationship, or correlator, which in its turn is held until present along with

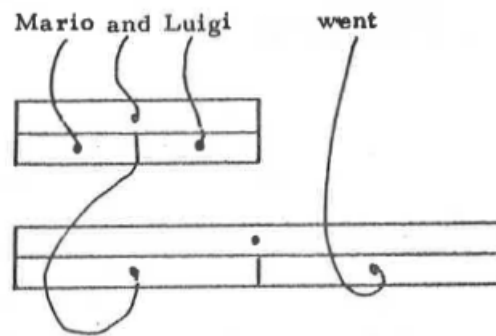
the second term, or second correlatum. Representing this structure in musical fashion, we would have:



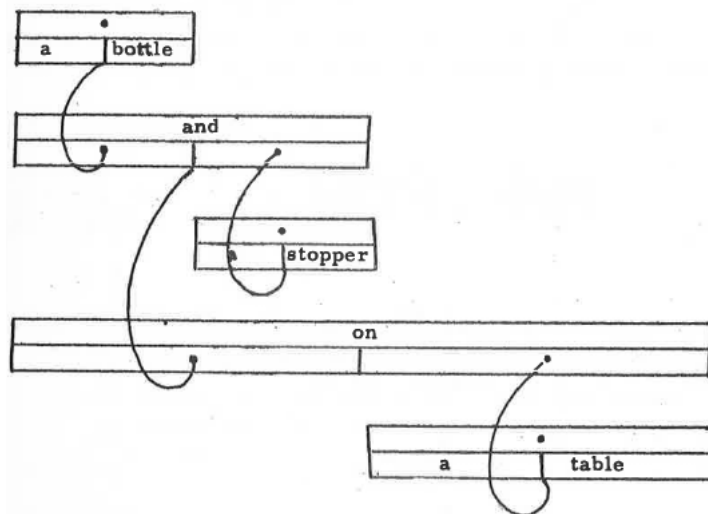
The triad, or correlation, in its turn, respecting the same temporal ordering, can take part as an element, that is, as the first or second correlatum, or even as the correlator, of a more ample correlation. For example, "Mario and Luigi went" designates a correlation characterized by the correlator "and", which enters, as first correlatum, the correlation characterized by the holding of the subject and its development. If to represent the correlation ere adopt the following graphic structure:



we shall have corresponding to the sentence:



The expression we considered before, "A bottle and a stopper on a table", is formed by five correlations:



This correlational procedure could not however be prolonged beyond six or seven seconds, without the first elements being inevitably lost. Our memory, as a holding of presence, would not allow it.

That which permits us to continue the correlational net is another of the functions of the memory which we have pointed out, the summarizing one, with which it is possible to take up in condensed form the thought which has already been performed; a function which in language for the most part is designated with pronouns: "Mario and Luigi went happily on their brand-new bicycles. They..."

Now, before seeing what this correlational analysis of thought means for a classification systematics, I shall complete the picture of our awareness of the work of the mind by showing how thought and language are connected. This would be of use also in understanding why this awareness is indispensable for the construction of a talking automaton, in programs for mechanical translation, summary, description, etc.

It is a matter of indicating in each correlation both the particular three elements which constitute it and the function which they perform in constituting it, that is, their place in its particular temporal dynamism. A correspondence between the two dynamisms, that of thought and that of speech, would appear to require six indications, three for the three particular things put into combination and three for the three particular functions carried out. However, since the correlational structure is fixed, that is, it is always the same, five indications are sufficient, in that, when the three things which are to be combined have been indicated, the indication of the place occupied by two of them implicitly reveals which place is left for the third. Anyway, evidently, a supplementary indication is necessary, which has to do with all the elements as a whole when the correlation takes part in another larger correlation.

In regard to these indications, although in order to ensure a one-to-one correspondence between thought and language there can be no fewer than five of them for each correlation, if one should be lacking, aid may be afforded in that, even if all orders of things, psychical, physical, categorial, etc., figure as correlata, as correlators we always have only mental categories of relationship, and these, at our particular historical moment, are rather restricted in number, between a hundred and two hundred, even among peoples with the richest thought and language.

A physical system for the functions of memory

First of all, the operating will have a constructive aspect which will break up the traditional organ-function scheme. In other words, the operating - to use a common metaphor - leaves a trace or an imprint which reminds us of a magnetic wire, a tape, a record, iron filing, and so on. Literal memory can be explained in this way. An example of this is the spider, which first spins its web and then walks along it, going over one or other of the paths it has already traced; a road network is much the same. Once these networks are built, not only do they answer for the impression of passivity proper to a man who feels impelled by memory to operate in certain ways, but also, if they contain intersections, they go some way to explaining certain associations, by means of the junctions, i.e., the nodes which lead off along different roads. However, this scheme would not answer for the selective and summarizing functions of the memory. These could be put down to a mechanism which transfers the first operation into another system, in the form of discrete constructs corresponding for instance to the units "presentiated" by the attention. Each of these units could thus become a point where similar units converge as they are produced. They could also direct and stimulate the constructs. An example of this would be a system of strings which give rise to a certain sound as they are reduced to a particular length. That length must remain constant so that, when other sounds occur, they make the particular string vibrate by resonance (apart from the resonances corresponding to the various harmonics). Let us imagine a violin in which a string is pressed by the finger at a certain point in order to obtain a certain sound. Once this occurs, the length is preserved on the wood of

the finger-board, as in fixed-note stringed instruments. Each gathering center would thus be able to carry out associative functions, providing distribution along the paths which have it in common and which have contributed to the convergence.

However, the material to be used for the summarizing memory would be lacking unless the collection of the units is differentiated according to one or more scoring parameters, for instance the occurrences and the time, in the recent or distant past, at which they took place. For example, if we use a rod for each string which lengthens whenever the string vibrates, the height of these rods could be used in both a selective and summarizing process. It would be enough, in fact, to run a rod at different levels, so that it may contact what was most frequently repeated, when it is raised, and what was least frequently repeated, when it is lowered. This would form the basis for a selective process, at the required degree of rejection.

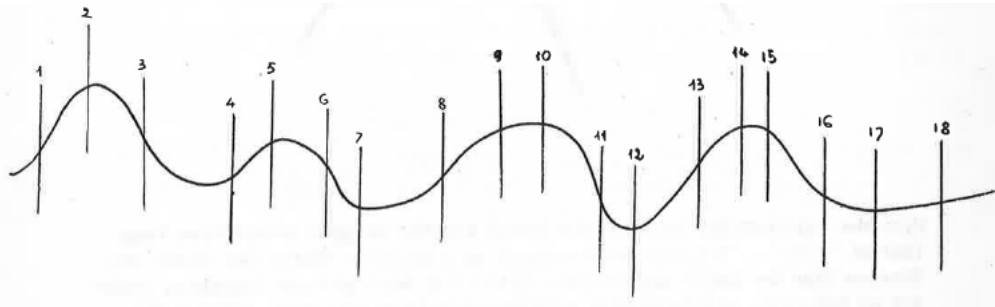
It will be noted that a procedure of this kind represents on a physical plane the well-known procedure carried out by somebody who is compiling the subject index of a book; this occurs, in our case, at the same moment as "the book is written". The headings refer to the particular subjects which are dealt with in the book; page numbers provide a reference and thus link the different points throughout the book however far they may be from each other. The amount of references corresponds to the height of the rods.

It will be noted that the subject index headings correspond to words or complete sentences, while memorization by attentional units carries with itself the operational articulation which is contained in them, which is normally an ensemble of operations. This also ensures the explicit presence of that which is implicit in linguistic expressions in relation to thought.

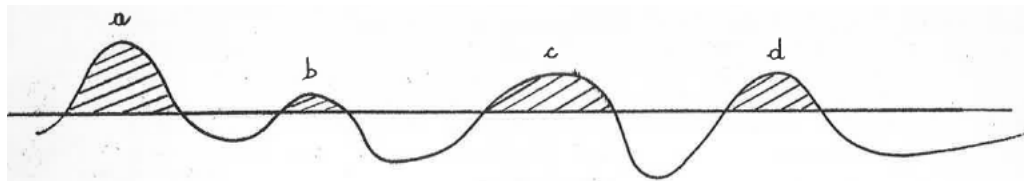
Here there is still some mystery as to how the new summarizing unit arises from the separate elements which are contained within it. To realize how this can and should come about, we may recall that the same situation exists at the beginning of the mentalization of the functioning of our organs, when the larger units are made up by the attentional play, which, having "presentiated" and fragmented that functioning, puts the fragments together again in relationship to each other. In both cases, the attentional activity obeys to some regularities, which are due to the physical nature of the organs and which can be investigated in terms of dependencies of the attentional functioning on the functioning of the other organs. We have already remarked this, when speaking of the "and" and the "with" in the example of the bottle and the stopper.

But it is clear that any categorization follows these dependencies before it is ever incorporated in one or another correlation of thought. It is enough to consider in what conditions we "see" a singular or a plural or a collective in a given situation, for example, applause or claps, and so on, and in what conditions we use only the plural and when we add "a few", "some" or "any", or, indeed, when we use a number, that is, when we count. These differed ways of speaking of things can be studied in relationship to the ratio between the size and distance of certain objects and the total size of the group of objects as a whole, and also in relationship to perception time, and the like. We can investigate when we use the passive and the active forms in the correlations, between subject, verb, and object, for instance "The peasants harvest the grain" or "The grain is harvested by the peasants".

The dependencies of the mental categories of relationship on the attentional units, as regards pre-memory and pre-condensing activity could refer to the separation and the reunion of the "presentiated" elements, see 1, 2, 3, etc.



in the case of memory the elements might no longer be the same but rather, for example, a, b, c, etc.



The straight line divides the more frequent elements from the less frequent ones

As regards the memory in its role of "maintaining present", it is characteristic of every dynamism that there is no sudden stoppage, but that it continues for some time, and, in the case of mental activity, the stoppage occurs at the point when the summarizing activity intervenes.

I feel that a study of the various functions of memory should be carried out not only on thought content and the various possible thoughts, but also on other situations, for instance a sequence of sounds, colors, tastes, and so on.

Hence I am an attempt to analyse a sequence of musical notes, of instance these:



asking myself what has become of it through the different functions of memory. Let us assume this sequence not as a simple succession of notes, but rather as a theme: this would be literally "recorded" as:



where the slurs can indicate the discrete attentional units. It should not be thought, however, that the transfer to the stabilizing convergence centers may involve only what we should speak of when we assume these sounds as isolated. In the continuation of presence itself the piece should keep to the order of succession, as pauses, notes, accents, arses and theses, rhythms, and so an. The problem which arises is to know exactly what is the meaning of maintaining and summarizing in this sense. If it mas a question merely of individual sounds one could imagine that the strings mere allowed to vibrate so that at the end they all vibrate "together" with a proportionate lowering of intensity. But the pauses, arses, theses, rhythms, and so on, must be maintained, since they too are constitutive of the particular thing perceived.

In this connection, let us not forget that the activity, however complex it may, may always be analyzed in the functioning either of organs which only change in state, place, etc, or of combination of them, in as much as the combiner is of the same type. Thus, since the functioning of all these

approach to the organic basis of mental activity is that of, biochemistry and biophysics. However, after so many years of divorce between the study of the mental and psychic sphere on the one hand, and the physical sphere on the other, I feel that the most important thing is to begin looking for possible links between these spheres, on the basis of the organ-function, relationship. Only in this way will the concepts of one discipline no longer appear incompatible with those of the other.

The substitution of one physical system for another will take place later on. But, once the necessary analysis in terms of operations has been carried out so that the organs which perform these operations as their functions can be imagined, the field of research is open and the methods are sound.

Milano June, 1966