

*Physiological Psychology and the mind-body problem 4.*  
*Towards a neurophysiological theory of conscious experience*

*Introduction*

Commenting on a paper by Putnam (8) in which he attempted to construct a theory of pain as a state of what he describes as a "Probabilistic Automaton" in a paper published in 1967 (7c) I remarked:

"I have a great deal of sympathy with Putnam's attempt to construct a machine model in terms of which it is possible to specify in functional terms what is involved in someone's having a pain. Where I cannot agree with him is in claiming that his theory is an alternative hypothesis which is somehow incompatible with the psychophysical identity hypothesis. I would prefer to regard this type of enterprise as one of the essential steps in a program designed to give some empirically testable substance to the psychophysical identity hypothesis. I have spoken in the past (7b) of the materialist thesis as a scientific hypothesis and I still believe that in an important sense this is right; but as it stands it is more in the nature of a proposal or "schematon", to use Putnam's term, for the construction of hypotheses than an actual hypothesis. We can see this if we ask the Popperian question, 'What evidence would count against it?' Clearly as it stands, we should have to know all that there is to know about the brain before we could be certain that it contains nothing which satisfies the logical criteria that have to be satisfied in order for us to be able to say that this brain process is that mental process; and how would we ever know that we knew all that there was to know? Only when we can formulate hypotheses which assert the identity of specific mental processes with specific brain processes, do we have a genuine scientific theory which is susceptible to empirical disconfirmation. And it is only when we begin to specify in precise functional terms what sort of processes these might be, that it becomes at all possible to make concrete suggestions as to their possible physical realisations" (7c pp. 61-2).

We also saw in the previous lecture, in trying to specify the logical criteria that need to be satisfied in order to show that a given brain process is one and the same thing as a given mental process, that

"the case for saying that experiences must be processes in the brain would be very much stronger if we could show, not merely that a brain process having all the properties of an experience is logically conceivable, not merely that the brain is a system of sufficient complexity to contain such a process, but that it is difficult, if not impossible, to explain the workings of the brain without postulating the existence of such a process within it." (Lecture 23, p. 3)

I also argued in the previous lecture that, in those cases where we give a micro-reductive explanation of such things as a substance, a stuff or a process, the micro-reductive explanation involves the assumption that the substance, stuff or process characterised in the micro-description is the same substance, stuff or process as that characterised in the macro-description and that therefore

"the empirical verification of such a theoretical explanation is *ipso facto* an empirical verification of the identity hypothesis." (Lecture 23, p.5)

In the light of these considerations it is evident that our next task is to examine the role and function of private experience and its place within the system of mental processes, mental events and mental states which we analyzed in Lectures 17-19 and compare this with what we know or suspect about the functional organisation of the brain, in order to find out whether among the processes which we need to postulate on other grounds, there is, as I put it in my 1969 paper,

"a process in the brain whose general functional characteristics and particular condition at any moment of time are such as to explain (a) the fact that human beings are apparently able to give first hand descriptions of a process occurring within themselves which plays an important part in the control of their behaviour, and (b) the character of these experiences at any one time as described by the subject." (7d p. 288).

### *The causal antecedents and consequences of conscious experience*

In discussing the what I called the presumptive criteria of identity in the previous lecture I omitted to mention what is perhaps the most useful of all such criteria when we are faced with the problem of finding a process

in the brain which can plausibly be identified with the mental processes of the individual. The criterion in question is one which I mentioned in discussing the identity of actions across different descriptions of them in Lecture 10, namely Davidson's (2) suggestion that two descriptions refer to one and the same event, if and only if the event referred to in the one description has the same causal antecedents and the same effects or consequences as that referred to in the other description. Like the other presumptive criteria of identity mentioned in the last lecture, this criterion is from one point of view merely a special case of Leibniz's principle of the Identity of Indiscernibles according to which two descriptions refer to one and the same thing if and only if whatever is true of the one is true of the other. There are however, a number of reasons for emphasising the identity of the causal antecedents and consequences in the case of the identity of events across different descriptions of them.

In the first place it is only events (in the wider sense which embraces any kind of occurrence) together with states of affairs which can properly be said to *have* causal antecedents and consequences. Furthermore, since an event in this broad sense is a change which takes place at or over time, we can only specify the particular event to which we are referring by locating it in terms of its position in a sequence of other events antecedent and consequent to it. In theory, of course, the time at or over which an event occurs can be specified in relation to any contemporary sequence of events; but an event inevitably fits much more snugly into the sequence of events constituted by its causal antecedents and consequences than it does into any other arbitrarily selected sequence of contemporary events. Moreover since a sequence of causally related events usually takes place within a fairly circumscribed spatially defined area, the specification of an event in terms of its causal antecedents and consequences also serves to fix the spatial location of the occurrence in question within certain limits.

Another relevant consideration here is that a micro-reductive explanation of the phenomenon constituted by the occurrence of events or processes of a given kind which, as I suggested in the last lecture, provides a presumptive criterion of the identity of the referent of the macro and micro-description in the case of events and processes, must necessarily take as its starting point the causal nexus in which the event or process in question is embedded.

Following this suggestion therefore, we may begin by examining the causal antecedents and consequences of conscious experience both in relation to other features and aspects of mental life, as described in Lectures 17-19 and in relation to environmental stimulation on the one hand and the publicly observable behaviour of the organism on the other.

*The causal antecedents of conscious experience*

As we saw in Lecture 17, in terms of the psychological concepts of ordinary language the immediate causal antecedent of a conscious experience is some kind of mental activity. One kind of mental activity is the activity of attending whereby the individual increases the sharpness, clarity and vividness of the sensory experiences deriving from one part of the total pattern of stimulation impinging on his sense organs at the time, relative to that deriving from other parts of the sensorium. Another kind of mental activity is that which I referred to as "picturing" whereby the individual creates experiences which resemble those deriving from sensory stimulation, but bears no relation to the way the sense organs are currently being stimulated.

As is implied by the concept of sensory experience or sensation, the principal determinant of the form and character of such experiences is the pattern of stimulation at the receptors and, more immediately, the pattern of neural activity in the afferent nerve fibres and the various sensory projection areas in the sub-cortical and cortical levels of the brain. The mental activity of attending or concentrating can alter the relative clarity and vividness of these sensorially determined features but it cannot alter their basic form and character. The form and character of the mental image experiences produced by the mental activity I have called "picturing", on the other hand, appears at first sight to be solely determined by the internal mental activity of the individual concerned. On reflection however, it appears that there are a number of examples of mental image experiences in which sensory stimulation plays an important part in determining their form and character. One well known example of this is the way in which sensory stimulation is incorporated into dream imagery, as in the case where the enuretic has a dream image of himself swimming in the sea (4). Another example is the way in which the noises of a moving train or of a large engineering works can be formed into the auditory image of symphony orchestra playing which is much more vivid than anything that can be achieved without such assistance. Other examples in which the role of the pattern of sensory

stimulation is even more decisive are the shapes seen in towering storm clouds, in the flames of an open fire or in the Rorschach Ink Blots (9).

Examples such as these suggest that the sharp line that we ordinarily draw between sensory experiences and mental imagery reflects the practical importance of distinguishing between reality and fantasy rather than any sharp dividing line that exists in the psychological reality between these two types of experience. It seems rather that there is a continuum of cases between those experiences whose character is solely determined by intrapsychic mental activity on the one hand and those whose character is strictly and wholly determined by sensory stimulation on the other and that the distinction which we draw between the mental activity of picturing and that of merely attending more or less closely to features whose character is determined by sensory stimulation is likewise a matter of degree rather than of kind, and that in reality the only sharp distinction to be drawn within the mental activities controlling conscious experience is between those aspects which involve publicly observable adjustments of the body and the receptor organs so as to alter the pattern of receptor stimulation and the type of central selection which has to be postulated in order to account for phenomena such as the "cocktail party effect" (1a). This view would suggest that even in those cases where mental images are constructed without any apparent incorporation of features derived from sensory stimulation, some part of the background sensory experience in the relevant sensory modality, which is weakly structured in the sense that it contains no very sharply defined figure-ground relationships, is given a distinct shape or form by the same active mental process as that which sharpens up the existing figure-ground relationships within the more strongly structured sensory experiences when these are brought into the focus of attention. Indeed part of the function of such overt movements of the receptor organs as the closing of the eyes in thinking may be to provide a weakly structured field of sensory experience in order to facilitate the construction of more vivid mental images than would otherwise be possible.

### *The effects of conscious experience*

I suggested in Lecture 17 that the immediate effect of conscious experience is the mental act or event of interpreting or construing the experience in a particular way, usually in the case of a sensory experience as a sensory contact with some feature of the individual's current stimulus environment. This mental act or

event of construing an experience in a particular way, I suggested, consists in the initiation, as a consequence of the antecedent mental process, of the subsequent and consequent mental state of believing or being, at least temporarily, inclined to believe that things are or were as they were interpreted or construed as being. Moreover if, as I argued in Lecture 19, there are reasons for thinking that the so-called "imageless thoughts" involve some kind of interpretation or construal of an antecedent conscious experience, it follows that all mental acts and events, including those such as deciding and inferring, which presuppose an antecedent mental activity of pondering, deliberating or calculating, involve some kind of interpretation or construal elicited by an antecedent conscious experience.

As we saw in Lecture 17, the mental states whose initiation constitutes a mental act or event, or which develop as a reaction to the way in which the experience is interpreted in the mental act or event, are of two basic kinds, mental dispositions which manifest themselves only when relevant circumstances or topics of discussion arise and states of mind or emotional states which colour the whole of experience and behaviour during the period of time over which they apply. With the exception of the distress aroused by sensations like pain and nausea and the pleasure aroused by things like meaningless patterns of sound and colour or certain forms of somatic and skin sensations, all emotional states or states of mind depend for their occurrence on some antecedent belief about or construal of the situation in which the individual finds himself and are to that extent indirect rather than direct consequences of a mental act or event of construing or interpreting a current experience in a particular way. By contrast all the mental states whose initiation constitutes a mental act or event are without exception mental dispositions, such as construing or understanding something in a particular way, believing or knowing something to be true, or intending to do something. Furthermore with the exception of the intention to do something which results from the mental act of deciding to do it, all these mental dispositions which occur as immediate consequences of and integral parts of a mental act are mental dispositions of a cognitive, as opposed to a volitional kind. Moreover, all cognitive mental dispositions, as well as all genuine intentions, require a mental act or event for their initiation. The volitional dispositions of wanting or not wanting something to come about, although, as I pointed out in Lecture 12, they frequently come into being as a consequence of the acquisition of a new instrumental belief and therefore, as an indirect consequence of the mental act of so judging, concluding or

inferring, do not come into being as a direct consequence of a mental act. In this respect the mental dispositions of wanting and not wanting something resemble states of mind with which they have close conceptual links in other ways, since as I pointed out in Lecture 13, to say that someone wants something entails that he will be (a) pleased if he gets or thinks he will get what he wants, (b) worried, if he thinks he may not get it, and (c) either angry or miserable if he thinks he has lost his chance of getting it.

Since as we saw in Lecture 12 & 13, the way the individual behaves, including his activity in controlling his experiences by attending and picturing, is determined, as we construe it in terms of the psychological concepts of ordinary language, by the nature of his various mental dispositions and his current state of mind and since and in so far as conscious experiences play an important role, directly or indirectly in establishing these mental dispositions and states of mind in the first place, it follows that conscious experience performs an important function in the determination of all aspects of human behaviour. Nevertheless, as I pointed out in my paper 'The concept of heed' (7a), and as I reiterated in discussing the properties of experience in Lecture 19, there are three aspects of human behavioural performance in which the role of conscious experience is particularly important and which cannot be adequately described in terms of ordinary language concepts without adverting to that role. The first of these three aspects of human performance which depend crucially on conscious experience is the control of skilled voluntary movement which, as I argued in Lecture 11, depends on the individual's paying close attention to and thus clearly and vividly experiencing the sensory feedback from his own movements as they develop in such a way as to

"amplify those movements that are falling short of what is required in relation to his objective and attenuate or suppress those movements that are in excess of what is required or tending in the wrong direction altogether." (Lecture 11, p. 9)

The second aspect of human performance which depends crucially on conscious experience is the ability to give a first hand description of what is currently the case or currently going on in the individual's stimulus environment as it impinges on his sense organs. Only in so far as his ability to give such descriptions depends, not only on sensory stimulation, but also on the sensory experiences produced by such stimulation and on the way he interprets those experiences, rather than on information derived from

other sources or at other times, can we characterise such a description as first hand. As I argued in Lecture 18, the ability to give introspective descriptions of conscious experiences is a by-product of this crucial role of conscious experience in our ability to give first hand descriptions of what is happening in our current stimulus environment.

Finally there is an important conceptual connection between the concept of conscious experience and the concept of memory in that one can only be said to remember something as opposed to knowing it, to be true by some process of inference, if and so far as one's present ability to make the relevant correct statements depends on a previous sensory experience and a consequent correct interpretation, either of the relevant environmental state of affairs or of some statement made by someone else, whether in the form of words spoken or of words written down on paper. Moreover, it is only in the former case, where one's ability subsequently to make the correct statement depends on experiencing and correctly interpreting the current state of one's environment at the time, that we can speak of someone's remembering some events which happened to him and which he personally experienced at the time.

#### *Mapping conscious experience onto Broadbent's Information Flow diagram*

Having located conscious experience in relation to its causal antecedents and consequences both inside and outside the mind, as we may conveniently call the system of mental processes, mental events and mental states described in Lecture 17, we are now in a position to ask whether there are any reasons for supposing that there exists within the brain a process having those same causal antecedents and consequences and a system of processes, events and states which are related to each other in the way mental processes, events and states are related.

In his book *Perception and Communication* published in 1958 Donald Broadbent (1a) has presented "a tentative information-flow diagram for the organism" (Figure 1) which represents in schematic form the interrelations between the various components which would need to be built into a machine which processed information in the way in which human beings process information as determined by experimental studies of human performance in the laboratory. In other words, Broadbent's diagram tries to represent the various functions which must be supposed to be performed by what are presumably



anatomically distinct parts of the brain, though without committing him to any view as to precisely which parts of the brain perform these different functions. However, since the general layout of the information-flow diagram with its flow of information from input to output, with back-tracking negative feedback circuits, reproduces the general layout of the brain as we know it from neuroanatomical and neuro-physiological research, it is not difficult to make some suggestions as to how it would map on to the actual anatomical structure of the brain.

The most striking feature of this information-flow diagram for our present purposes is the unit, called by Broadbent the "*Selective Filter*" whose function is to protect the main information processing unit, the "*Limited Capacity Channel*" from being overloaded by more information coming into the system *via* the senses than the unit is capable of processing. The effect of the filter is to allow only a part of the total information coming in from the senses to pass through to the limited capacity channel at any one moment of time. The filter however, is not a fixed device which allows only certain types of input to pass through for processing. It is an infinitely variable filter through which any input can pass, provided that not more than a limited amount of information passes through at any one time. Which particular part of the total input at any moment passes through depends on what Broadbent calls the "*filter setting*". The setting of the filter is controlled from within the system by a feedback loop which is shown in Broadbent's 1958 diagram as emanating from what he calls the "store of conditional probabilities of past events". What he has in mind here is that if a stimulus event *A* is regularly and repeatedly followed by another stimulus event *B* the occurrence of an input corresponding to a stimulus event of type *A* will come to have the effect of setting the filter so as to admit a subsequent input of the type corresponding a stimulus event of type *B*. The organism will thus be prepared to respond to stimulus event *B* when it appears. It will "expect" a stimulus event of type *B* given a stimulus event of type *A*.

It goes almost without saying that Broadbent's selective filter mechanism performs precisely the same function as the mental activity of focusing attention or concentrating on a particular part of the array of environmental features which are currently impinging on the individual's sense organs, as it has been described from an introspective standpoint. Not only does it make sense of the observation that only a limited part of the total sensory input at any one moment of time is in the focus of attention, it also makes

sense of the notion of attention as an intrapsychic activity in terms of the notion of filter setting by means of feedback loop coming from the output end of the system.

Broadbent himself recognises that, as he puts it,

"the traditional language of consciousness and attention deals largely with the problem we have mentioned. A work such as that of William James (5) points out repeatedly the facts which are painfully restated in our different and unfamiliar terms" (1a, p. 58).

Nevertheless, Broadbent claims that his concepts were developed purely in order to account for the results of experimental studies of such phenomena as the selective perception and retention of two or more simultaneously presented auditory messages, and that it was no part of his initial intention to reproduce the relationships implicit in the psychological concepts of ordinary language. This isomorphism between the two is simply a reflection of the fact the two conceptual systems are drawing attention to the same features of the same behavioural phenomena.

Having identified the mental activity of paying attention to a selected part of the total current input (and, in the light of the considerations presented above, the mental activity of picturing or imagining such inputs in their absence also) with the process of filter setting as described by Broadbent, it is not difficult to make a number of other identifications between other mental concepts and other features of Broadbent's information flow diagram. Since as I pointed out in Lecture 18 the role of mental activities such as attending and picturing is to regulate or generate the individual's conscious experiences and since, as I also pointed out, it is only the effect of such activity and not the activity itself which constitutes the individual's experience, it is clear that the conscious experience of the individual must be identified not with the process of filter setting, nor yet with the activity within the filter, but with its output, represented in Broadbent's 1958 diagram by the line running from the selective filter and forming the input into the limited capacity channel. In other words conscious experience corresponds to what Broadbent in his recent book *Decision and Stress* (1b) has called the "evidence" about the current state of the environment which is generated by the selective filter and received for processing by the limited capacity channel. In this more recent survey of the field, Broadbent has introduced a number of elaborations of and modifications to the theory as presented in 1958, which although they have been introduced to account for new experimental evidence which has come to

light since 1958, rather than to accommodate distinctions embodied in the psychology of common sense, in fact make it much easier to map the psychological concepts of ordinary language onto his theoretical scheme. Unfortunately he has not produced a new version of the information-flow diagram incorporating these modifications and elaborations. I have therefore, produced my own revised version of the diagram (Figure 2).

A comparison of this revised diagram with that of 1958 shows the following changes:

- (1) The feed back loop from the output of the limited capacity channel into the short term store or buffer is eliminated in accordance with Broadbent's *fourth modification* (1b p. 14).
- (2) The output of the selective filter which constitutes the input into the limited capacity channel and which Broadbent now calls the "evidence" about the state of the outside world is no longer shown as a single line representing the passing on for processing by the limited capacity channel of one part of the input to the total exclusion of the remainder. Broadbent now recognises that

"when listening to speech from a loud speaker placed on our right hand side and ignoring speech coming from the left... sounds from the left side are not shut out from all possibility of affecting the limited capacity system; they merely receive less weight, because fewer states of evidence can result from any particular stimulus on the left ear." (Broadbent's *second modification*, 1b p. 13).

This is expressed on my revised diagram by showing all the inputs as proceeding on through the filter into the limited capacity channel, but with the exception of the input on which attention is focused which is shown in **bold** in contrast to the other filter outputs which are not so emphasised indicating thereby the peripheral or background nature of their effect on the limited capacity channel.

- (3) The limited capacity channel is now identified as a system whereby the organism assigns each input into the system or state of evidence, as Broadbent now calls them, to a particular *pigeon hole* or *category* within a kind of built-in classification system, which the organism gradually develops in the course of its life history, and is constantly revising by means of a process of learning which Broadbent calls "*category setting*". It is not difficult to appreciate that the event whereby a state of

evidence is "*pigeon-holed*" by the limited capacity channel corresponds in terms of common sense psychology to the mental act or event whereby an experience is interpreted or construed in a particular way. (Broadbent's *second modification* (1b pp. 13-14)

- (4) The output of the limited capacity channel, the pigeon-holing or categorizing system is now identified in accordance with Broadbent's new terminology as a "*category state*". (Broadbent's *fifth modification* p.15) This clearly corresponds to what I would want to call the categorical (as opposed to hypothetical) state which underlies and explains, but is not identified with, the mental state of interpreting, understanding or construing an experience in a particular way which we characterise in ordinary language in terms of the proposition which the individual is said either to entertain or believe as the case may be.

If at this point I may be permitted to go beyond the account which Broadbent has given, I would suggest that we can understand the selection of a particular category state in terms of a high level switching in and switching out of various output and feedback circuits within the brain which sets up the system in such a way that, given certain subsequent inputs, a particular output or set of outputs will occur, though no output of this or any other kind need appear when the initial selection is made, nor if the subsequent input fails to appear at any later time. The selection of a particular category state may be compared to the completion of an electrical circuit which energises an electromagnetic relay the effect of which is to open and close a number of make, break and changeover contacts in other circuits. The fact that a particular set of contacts is thereby closed need not mean that the circuit in question is thereby completed. It may well be that the closing of another set of contacts on another relay is required before the circuit is made and an output occurs. This explains very neatly what happens when a thought occurs to someone which he is subsequently able to express in words, although no actual words occurred to him at the time. Given that the part of the circuit controlling the verbal output in question has been closed by the energising of the relay, a subsequent input, e.g. being asked a question about the topic under discussion, will have the effect of energising another relay the closure of whose contacts will complete the circuit and the appropriate verbal output will occur. I would envisage that such a relay would have contacts

controlling a variety of different output circuits, motor as well as verbal, the completion of each of which would depend on the subsequent closure of contacts on a relay selected by a different input in each case. This accounts both for the variety of different behaviours which constitute exercises of the same mental disposition as well as for the correlation between what a man says and what he does on which we rely both in predicting his behaviour in mentalistic terms and in characterising his behavioural dispositions in terms of what he would be inclined to say. Likewise we can use the notion of the breaking of certain other circuits by the action of the relay to explain such phenomena as the way in which interpreting something as a round object, excludes the possibility of simultaneously construing it as a square object.

It should be emphasised, however, that in terms of this model, the energising of such a relay corresponds to the situation in which someone has something actively in mind at the time, rather than to a belief which is held over stretches of time during which the individual attends to and thinks about many other things. A belief in this latter sense would correspond to the existence within the system of circuits whereby the relay in question is energised whenever a particular input or a particular set of inputs enters the limited capacity channel. It is some such distinction as this I assume, which Broadbent has in mind when he distinguishes between *pigeon-holing* and *categorising* and between *pigeon-hole-setting* and *category setting* (Broadbent's *fifth modification* (1b p. 15) though I confess that I find his exposition of these distinctions too difficult to follow to be at all sure of this point.

- (5) Instead of the "store of conditional probabilities of past events" shown on the 1958 diagram with an input from the limited capacity channel and with outputs to the selective filter and the "system for varying output until some input is secured" we now have a *long term memory store* in which

"access to the long-term store is through the categorizing stage, not only in input but also in retrieval." (Broadbent's *sixth modification*, 1b p. 16)

It is perhaps worth pointing out in this connection that I do not myself favour an information storage theory of memory such as is implied by the concept of a memory store. I

would prefer to construe memory in terms of the facilitation and inhibition of certain pathways through the system, particularly within the limited capacity channel, on the analogy of the setting up of new circuits whereby particular inputs serve to select certain relays and the relays acquire new contacts controlling new output and feed back circuits as envisaged in the model described above.<sup>1</sup> I feel that Broadbent's conception may indeed be moving in a similar direction when he warns us that if we represent

"the outflow of information from the long-term memory as passing only through the categorizing state . . . , one must remember that the category setting is itself a form of long term storage." (Broadbent's *sixth modification*, 1b p. 16).

A point that needs to be made in connection with the way I have shown the long-term memory on my revised version of Broadbent's diagram is that the input into the long term memory should not properly be shown as travelling from the category state along the line which I have marked as "conditional circuits". These conditional circuits are circuits leading to outputs which become effective only when another input is received subsequently, whereas the registration of a categorical input so as to be available for subsequent retrieval is presumably an automatic unconditional effect of the selection of a particular category state. The representation of the input into the long term memory in this misleading way is purely a matter of diagrammatic convenience.

- (6) In order to accommodate what Broadbent has to say about the role of "*stress*" in his *seventh modification* (1b p. 16) I have introduced another block into the diagram on the output side of the category state which I have called the "*servo*". This is a mechanism of which I conceive, in Broadbent's words, "as affecting general properties of the entire system". This general effect on the system as a whole is indicated on the diagram by showing outputs from the servo leading to the filter, the limited capacity channel and the output command signals. The nature of this effect, as is implied by the description of it as a servo mechanism, is conceived in terms of the facilitation or inhibition of the activity in other parts of the system. If, again, I may be permitted to go beyond

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<sup>1</sup> Needless to say these words were written more than ten years before the advent of Connectionism. [Added June 1998]

anything Broadbent has said, I would conceive of these facilitatory and inhibitory effects as being of two different kinds, (a) general effects whereby the level of activity or arousal within the system is increased, as in excitement or tension, or reduced as in relaxation or depression, and (b) selective or specific effects on the particular activity currently occurring within the system. These specific effects are either *redintegrative* in that the current activity of the system is maintained and its reinstatement on similar occasions in the future promoted, or *disintegrative* in that the current activity of the system is disrupted and its replacement by alternative patterns of activity promoted as implied by the Law of Effect.

The postulation of a specific servo-mechanism within the organism's behavioural control system is justified not only by the evidence of objectively observable behaviour and the concepts of motivation and emotion as they occur in common sense psychology, it is also supported by the fact that a centre with precisely these functions is known on the evidence of neuro-physiology to exist in the *hypothalamus*.

One important feature of emotional reactions (construed on this model as changes in the setting of the servo-mechanism) is that they occur as involuntary passive reactions to experiences and the way experiences are interpreted. This feature is represented on the diagram, as I have drawn it, by showing the output from the category state into the servo, together with the feed back loop to the filter, as "unconditional" as opposed to "conditional circuits" issuing from the category state. In other words, in terms of the relay model they are circuits which are immediately completed and which therefore, become effective as soon as the relay is energised, unlike the conditional circuits leading to the effectors which do not become effective unless and until there is (a) the appropriate motivational output from the servo and (b) a subsequent input which is interpreted as a sign that the occasion or opportunity for the behaviour in question has arrived.

A feature which I have not succeeded in representing on the diagram is the distinction which I drew between the distress occasioned by pain or the pleasure occasioned by bodily sensations which does not depend on how the experience is interpreted in the way that other emotional reactions do. One way of representing this might be to draw a line directly from the filter output

(EVIDENCE/experience) as an input to the servo, thus by-passing the limited capacity channel. Another way would be to treat the servo reaction in such cases as a component part of the way the experience is interpreted, i.e., as part of the category state, rather than as an effect of it.

- (7) Finally I have replaced the unit in Broadbent's 1958 diagram described as the "system for varying output until some input is secured" by the notion of the "*command signal*" which Broadbent has made use of in his more recent work. The argument for making this change is firstly that the notion of varying output until an input is secured takes no account of the initiation of the behaviour in the first place which clearly requires an initial command signal, and secondly that each variation of behaviour in response to a feedback input from the senses indicating how the movement is developing requires a command signal to initiate it. Furthermore, since the conditional nature of the circuits leading to effector output is indicated on my version of the diagram, the fact that a subsequent input is needed in order to effect such variations is already allowed for. Consequently I would argue, Broadbent's system for varying output until some input is secured, is largely if not wholly accounted for in terms of the modified arrangement I am proposing.

### *Mapping Mental Life onto the Brain*

Having mapped the various psychological concepts of ordinary language onto this modified version of Broadbent's information-flow diagram in the way I have indicated, we are now in a position to map the different mental activities, mental processes, mental acts, mental events, mental dispositions and states of mind or, rather in the case of mental dispositions and states of mind, the categorical states of the microstructure of the organism underlying them, onto the anatomical structure of the brain, by identifying the various parts of the brain whose functions appear to coincide with those of the various units in the information flow diagram.

As far as this aspect of the problem is concerned I have nothing significant to add to what I said on this topic in a paper (7d) published in 1969 the relevant portion of which I reproduce below with a few changes to bring it into line with the revised version of Broadbent's information-flow diagram and the relation of the different mental concepts to it which I have presented in this lecture.



"The first point to be made in translating Broadbent's model in terms of the physiological and anatomical hardware is that the output of the filter and the input into the limited capacity in which, on the present argument, conscious experience consists, will not be some special kind of electrochemical process at the molecular, atomic or sub-atomic level of analysis, but rather a complex pattern of activity involving the excitation and inhibition of a very large number of individual neurones. This pattern of activity will be distinguished from other similar patterns of neural activity, not so much by any special peculiarity of the way the neurones in question interact, as by the function which neural activity in this system of neurones performs in the process whereby information is transmitted from input to output. Since as we have seen, the pattern of neural activity in question is one which connects the output end of the filter mechanism to the input of the limited capacity channel and since the function of the limited capacity channel is to preselect certain rather general strategies of behavioural output, both verbal and motor, these are the kind of functional relationships we need to look for within the anatomical lay-out of the brain.

"Now there is a considerable body of evidence which has accumulated in recent years which suggests that the functions attributed by Broadbent to his hypothetical filter mechanism are in fact performed in the brain by the *reticular formation*. We also know that the reticular formation plays an important part in the control of the general level of consciousness, particularly the process whereby the individual is aroused from sleep. The evidence relating to the functions of the reticular formation has been reviewed by French (3) and Lindsley (6). It seems unlikely however, that conscious experience will turn out to be a process in the reticular formation itself. Conscious experience, we have suggested is the output from the filter mechanism, not the mechanism itself. It is something that is regulated by the reticular formation rather than something that takes place in that part of the brain. The reticular formation as a whole appears to perform a regulative function with respect to many parts of the nervous system, but in its capacity as a filter mechanism it is the control it exercises over the activity of the sensory projection areas of the visual cortex that is of most obvious importance.

Furthermore, if we try to locate the area of the brain mediating those functions which we have attributed to the limited capacity channel into which the output from the filter is channelled, our attention is again directed to the cerebral cortex and particularly to an area lying roughly midway between three important sensory projection areas, the visual area in the occipital lobe, the auditory area in the temporal lobe and that for somatic sensitivity in the parietal lobe, where in the case of the dominant hemisphere, brain injury tends to produce disorders in the interpretation of speech and language, regardless of the modality through which it is presented and perceived. It is not inconceivable that a similar area involved in the interpretation of sensory input in motor, rather than in verbal terms, exists in the corresponding position in the non-dominant hemisphere. One is tempted no doubt naively, to think of conscious experience, in so far as it is capable of being reported and described by the introspecting subject, as a pattern of neural excitation converging on this crucial area for the interpretation and productive formulation of speech from the sensory projection areas" (7d pp. 291-2).

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Figure 1

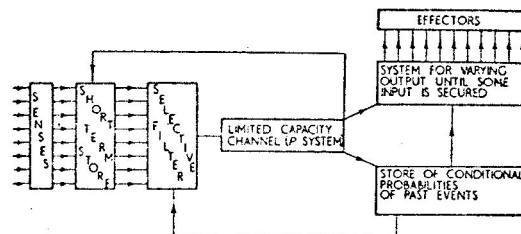


Fig. 7. A tentative information-flow diagram for the organism, as conceived at the present time. This diagram includes many of the views put forward by various workers in recent years: it covers Brown's research on immediate memory, Deutsch's and Uttley's on learning and the work on anticipation and refractoriness as well as that on noise, multi-channel listening and prolonged performance.

Figure 2

Tentative Information Flow Diagram  
for the Organism (adapted from Broadbent, 1958).

