

A NEW TYPE OF BEHAVIOUR THEORY

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I. *Introduction* (pp. 304–305). II. *The mechanism of performance* (pp. 305–307). III. *Behavioural sequences, innate and learned* (pp. 307–309). IV. *Learning* (pp. 309–311). V. *Quantitative consideration* (pp. 311–313). VI. *Analysers and output* (pp. 313–314). VII. *Conflict and repression* (pp. 314–316). VIII. *Summary* (p. 316). *References* (pp. 317–318).

I. INTRODUCTION

The theory put forward in this paper is logically unlike conventional psychological theories. These at best give us equations expressing certain correlations of the phenomena of behaviour. A student of learning theory, for instance, will find much information about the conditions of learning. He will be disappointed if he asks existing theory to explain the phenomena with which it is concerned, for it is merely a generalization about them (e.g. Hull, 1951). There is at present no hypothesis concerning behaviour which is like those ideally employed in other sciences.

Such an explanatory theory is a formal system consisting of elements which are defined by the relations existing between them. This system is furthermore given an identification such that from the system thus identified now follow consequences in terms of the phenomena to be explained. The identification need not be unique. The same formal system may, by making the suitable identifications, be used to explain, say, the behaviour of a machine and the behaviour of an organism.

The formal system or its identification cannot be deduced from the generalizations concerning the phenomena. On the other hand, an acceptable explanatory hypothesis must entail the correct generalizations; it must make the right predictions. One may, of course, predict on the basis of empirical generalizations, but to work on this level is not normally considered ideal in science.

If these points concerning the nature of explanation are correct, then the view that explanation in psychology waits upon neurological advance is wrong. It also follows that a psychological theory need not be physiological speculation. We do not need to give the elements in our system an identification in terms of actual or imagined neural properties or units. This of course is not to deny that the final verification of an explanatory hypothesis in psychology will not come from its direct identification in terms of neuronal systems, but to assert that the framing of a hypothesis can precede its confirmation. We can say that the organization is such-and-such a system without being obliged to state the precise embodiment of this system. It also follows from these points that a theory may, and must, use elements not wholly definable in terms of the phenomena to be explained. A hypothesis must go beyond the phenomena so to speak, whilst it does not need to rely on available observation from other fields. The atomic hypothesis went beyond the facts of chemical combination then known, and assumed the existence of a certain type of system, atoms with special properties, to explain them. Atoms had not been observed, nor was it possible to identify them physically.

The hypothesis set out in what follows has many limitations, some of which are deliberate. This paper confines itself to performance of acts and learning in appetitive behaviour. Reasoning and avoidance behaviour are excluded as it is hoped to deal with these in a future paper.

Also, where undue complications of the hypothesis would have resulted from increased predictive power, simplicity has been preferred.

The paper begins by outlining the basic unit which may be supposed to underlie 'a simple act'. Then it describes the relations of the basic units among themselves. This is assumed in order to explain the performance of habits and instinctive behaviour. After this an explanation is put forward of how experience modifies this system to produce the phenomena of learning. Lastly, conflict is dealt with.

II. THE MECHANISM OF PERFORMANCE

There is no unit of behaviour but there is a unit mediating behaviour. Such a unit is presented by a list of the elements used in the system, together with statements concerning the relations of these elements among themselves. (Each numbered statement throughout the paper will describe a fresh feature of the system.)

There are five elements. These are called: (a) an analyser (a receptor system); (b) a link; (c) a motor (or effector) organization; (d) an environment; (e) an internal medium.

There are three kinds of relation. These are called: (a) activating; (b) switching off; (c) causing to vary.

The elements are connected by the relations to form the basic unit in the following way:

- (1) When the link is active, the motor organization is made to vary.
- (2) The variations in the motor organization cause the environment to vary.
- (3) A particular variation of the environment activates the analyser.
- (4) The activated analyser switches off the link.

Activity in the link and so in the motor organization is terminated by the activation of the analyser attached to the link (see Fig. 1).

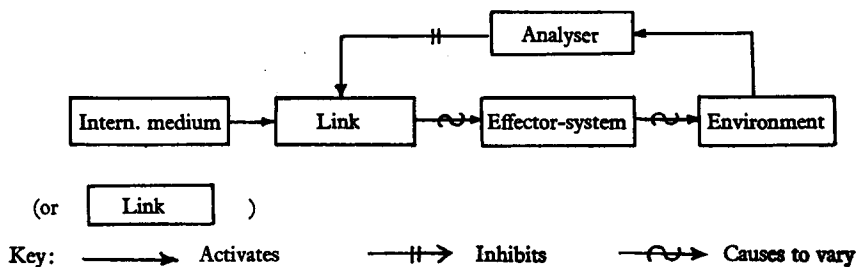


Fig. 1. *The unit.* The internal medium activates the link which causes the effector system to vary. This brings about changes in the environment which may eventually fire off the analyser attached to the link in this unit. The information from the analyser acts as feed back.

A 'stimulus' does not evoke a response, it terminates it. A dog will stop drinking when the receptors in its mouth and throat have been sufficiently stimulated (Bellows, 1939); a man will cease pronouncing a sound when he has heard himself doing so. Delay this information and he will stutter (Fairbanks & Jaeger, 1951). The question of the initiation of activity is therefore raised.

- (5) One kind of link is set into activity by a specific or general feature of the internal medium.
- (6) Another kind of link is activated by its neighbour.

No link is activated by both; either it is of the kind which is activated by the internal medium, or of the kind activated by another link.

Let us now expand the statements made and consider the units whose links are activated by the internal medium, applying the theory to some concrete examples. It has been stated that in some of these units, the link is set into activity by some specific change in the internal medium. This is the case in hunger, thirst, mating and instincts of a like sort. It is held that for each of these there exists a link, sensitive to a particular chemical state of the fluid surrounding it. The link responsible for male mating behaviour may be sensitive to male sex hormones: that concerned with thirst, cellular dehydration, and so on. The exact chemical identification of the states is, of course, unimportant to the theory *qua* system and is only tentative. Each of these links, it is held, is innately connected to a differing analyser or a set of analysers and so to differing sets of receptors. The link sensitive to cellular dehydration is in all probability connected to receptors in the mouth and throat, those mediating some of the special appetites to taste receptors, and the link mediating hunger mainly to receptors in the stomach. These identifications are again tentative. They appear plausible on what little evidence there is on this important subject.

(5a) The change in the internal medium irritates the link in proportion with the magnitude (or perhaps in some cases, rate) of this change.

The total amount of activity in the link will be a product of the amount of this change and the state of the link, which (4a) is determined by the amount and recency of the firing of the analyser innately connected to the link. The link sets the motor organization into activity. When the analysers connected to this system fire off, the irritability of the link to the particular chemical change which set it off begins to decrease. Therefore the time taken for the analyser to decrease the irritability of the link below threshold will vary with the amount of the change in the internal medium. The cessation of activity in the link will occur in spite of the continuance for some time or permanently, of the chemical state which initiated the activity, and this is the case in a normal animal. The mechanism of 'need' is therefore not a simple homeostat. However, in some of these 'needs', the particular chemical change which occasioned the activity which then led to a discharge in the appropriate analysers will be reversed as a remote consequence of the discharging of those analysers in an intact animal. For instance, in drinking, when the appropriate receptors have been stimulated to an extent sufficient to lead to a cessation of drinking, water must have entered the stomach. This water will then slowly redress the change which occasioned the drinking, comparatively long after drinking has ceased. If we assume that this type of system is in fact operating when we speak of the so-called instincts and physiological drives, we can explain the following observations.

The onset of these activities is not due (*pace* Hull, 1933) to intensity of stimulation. Selective abolition of afferent impulses has not been found to eliminate such activities (Tsang, 1938; Bash, 1939), nor has selective intensification of these produced an excess of activity (Montgomery, 1931). On the other hand, the onset of these activities appears to coincide with chemical changes in the blood (Beach, 1948) which Lashley (1938) concludes act centrally. It is then that such activities appear and persist until certain specific stimulation occurs. It has therefore been said that instinctive activity is caused by a stimulus deficit. (This looks paradoxical because the S-R theorists have long confused the two notions of stimulus and cause.)

When appropriate stimulation has occurred, activity ceases, even though the chemical change which occasioned the activity persists. A dog with an oesophageal fistula will drink the same amount as if water had entered its stomach (Bellows, 1939). The rats in Kohn's (1951) recent experiment stopped lever-pressing when a nutrient solution was inserted directly in their stomach, before it could have had an appreciable effect on the chemical changes which occasioned that activity. Further confirmation of Kohn's results and the interpretation put on them by the present theory is to be found in experiments performed by Miller & Kessen (1952), and also by Berkun, Kessen and Miller (1952).

This experiment also supports the present theory against that of Tinbergen (1951). Tinbergen believes that so much need is worked off or released in so much activity. After this release has taken place, activity ceases. But in this experiment no usual effector discharge occurred, and yet the animals appeared no longer to be hungry. It is plausible to believe, however, that certain receptors in the stomach had been stimulated, and this, according to the present hypothesis, is sufficient to explain why the animals were no longer disposed to eat.

The case of a dog with a full stomach which nevertheless drinks in gradually decreasing amounts after varying intervals (Bellows, 1939), might appear to contradict Kohn's (1951) results and with them the present theory. But the reader must be reminded that the dog was thirsty and the rats hungry, and that it has already been stated that the receptors remotely concerned with switching off thirsty behaviour lie in the throat and mouth, whereas those concerned with hungry behaviour lie mainly in the stomach.

The activity of the links, in some units (see Dennis, 1939) does not seem to rise or fall with fluctuations in some particular chemical state. Their activation seems to be due to some general feature of the constitution of the organism. Their existence is postulated because of the imperfect correlation, say, between the physiological needs and some appetites (Young, 1948) and because of certain preferences some of which might be called aesthetic.

Concretely interpreted, the hypothesis assumes that an animal, when we observe its performance, is searching for a given 'stimulus' or combination of 'stimuli' and that its performance ceases only when it has found them. When a man is searching for a shilling, he will ignore all 'stimuli' besides the shilling, and when he finds it his searching will cease. (This is of course an ideal case.) The activity ceases because certain specific analysers connected to the link causing the variations in output are fired off and switch off the link. The firing off of other analysers will be 'ignored'.

III. BEHAVIOURAL SEQUENCES, INNATE AND LEARNED

To account for a whole behaviour sequence, such as the running of a maze, this hypothesis is extended in the following manner. The links in some units are exclusively activated by another link (see Deutsch, 1954).

- (7) It is postulated that there is a single row of links, each link having only two neighbours, and the first and last only one, and that the first links (or the first few) are activated by the internal medium and these in turn excite the rest of the row of links which are only activated by an excited neighbour.

The first link is connected to the second, the second to the third, and so on. The first activates the second, the second the third. Therefore if the activity in the second ceases,

it also ceases in the third. The first link, however, will remain active, as follows from the above rule.

- (8) Secondly, it is postulated that if all the links are active only the last one in the row (our number three) will vary output fully.

When activity in number three has ceased, number two will vary output. Number one's variation of the output will be almost completely inhibited when number three is varying output, but number two more partially so, as the inhibitory effects of each link on the output of the others are additive. Hence the system will display 'anticipatory' or 'preparatory' behaviour, a special type of which is the conditioned response. Anticipatory behaviour will appear only in certain conditions (as a corollary of a rule given later, which states that the link with a higher rate of firing will gain control of an output unit in case of competition for it). Hence the system would show such behaviour when the two links acted on different output units. For instance, a rat can run and munch and salivate at the same time, but it cannot run and lie down at the same time.

Thus we have two rules concerning the row of links. The first states that the row is activated from its first member through each member in turn. (The first member underlies the aim last in time to the observer, e.g. feeding in the goal box in the maze.) The second states that an active link partially inhibits variations in output in all the links through which it is activated and that this inhibition is additive (see Fig. 2).

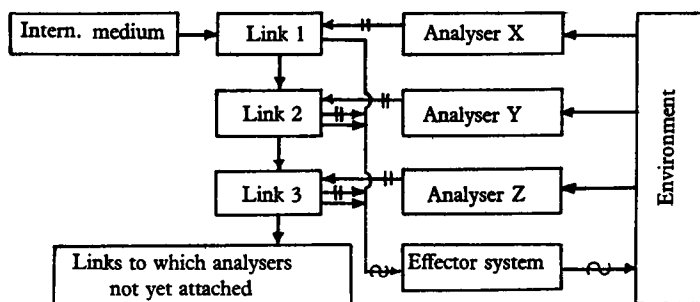


Fig. 2. *The organization of the chain.* The activation of a link activates the succeeding link. The activation of a link partially inhibits variation in effector system by preceding link. (Activation of a link only occurs when it has an analyser attached.) For key see Fig. 1.

We thus have a system which will pursue aims in turn, in a predetermined sequence. When it has run through the sequence, it will cease to be active. For when it has achieved its final aim (our number one in the sequence), there are no more activated links in the chain and therefore there is a cessation of variation of output. We have here a hypothesis which enables us to look in the same way at performance both instinctive and learned. Even if no new predictions could be made on it, it would still be of value as a co-ordinating and unifying hypothesis. Secondly, this system, owing to the first rule for the chain and the rule which states that a link is switched off when the analyser to which it is connected is touched off, will show a very interesting property. It will eliminate blind alleys or 'superfluous' moves, and break down on detour problems. This is deduced in the following way. Let us say that our row composed of three links is activated. Link number three will be varying output. If by chance the analyser connected to number two is fired off before the analyser connected to number three, link number two will be switched off, and with it link number three. Link number one will then vary output. The system will not

persist in pursuing an aim if that aim has been short-circuited, so to speak. If analyser number three is fired off by a cue up a blind alley, and analyser number two by a cue past the blind alley, the animal will not go up the blind alley, but pursue an aim nearer in order to the final goal. In some cases, that is in detour problems, the animal is allowed to see the goal but is not allowed to reach it except by pursuing aims which are now short-circuited by the firing off of analysers attached to links nearer in the chain to the first.

The activity in the row of links is transmitted by each member in turn from its first member. This first member is sensitive to changes in the internal medium and is set into activity by them, though its activity is cut short when the analyser which is connected to it is touched off.

- (4a) Any link in the chain will take some time before it resumes full irritability after being switched off. It will be in a refractory phase.

Hence this first member will take some time before it resumes activity even though the internal medium may not change.

So far, it has been said, a system has been constructed consisting of five elements with three kinds of relations holding between them. The relations existing between them fully define the elements. The relations themselves can be given various physical interpretations, but they cannot be defined within the system. The psychological interpretation the system has been given has already been made clear both by the choice of words to label the various elements and relations and by the examples used to make the system clear to the reader. But one could equally well have chosen to interpret the system another way by giving it a meaning in terms of valves, relays or mechanical contrivances. In fact, the writer has built an electro-mechanical model embodying the main features of the present system, which is capable of learning mazes and discriminations, of eliminating blind alleys and of Maier-type reasoning (Deutsch, 1954).

IV. LEARNING

So far the connexions between the analyser, chain and effector system have been regarded as fixed. This may be the case in the system underlying instinctive behaviour. Here the variation in motor output may be largely absent too.

The system already outlined would not be capable of learning. The writer has supposed that there is a row or chain of links, each acting on others in the way described, with all the links already connected to analysers and output units.

- (9) Attached to the end of each such a complete row are a great number of links also in a row, to which no analysers are yet attached.

(This means they will not be activated. A link to which no analyser is attached cannot be activated, according to a rule given later.)

- (10) When the row is switched on from its first member many fresh analysers will be fired off in a novel situation before the analysers already attached to the row.
- (11) When an analyser already attached to a link in the row is fired off the fresh analysers will be attached to the free links at the end of the row. The fresh analysers, which fired off nearest in time to the analyser already attached, will be fastened to the free links nearest in order to the links already occupied by analysers, so that temporal proximity of firing of analysers will lead to ordinal proximity of attachment on the row of links.

This is done by an ordering network acting in the following manner. Every analyser is connected to this network. As an analyser not already connected to a row of links fires, it

will be placed provisionally on the first free link attached to a row of links already occupied. If an analyser which is already occupying a link is fired off next in time to this fresh analyser, the fresh analyser will then be fastened to the free link on which it was placed. Next time this row is switched on, this previously free link will be the first to vary output. An animal will thus seek out the stimulation which occurred before the stimulation which it was seeking on a previous occasion (unless it is 'short-circuited', of course, in the same way as a blind alley).

If, however, the firing of an already attached analyser does not follow next in time after the firing of the analyser unattached to a link, but on the contrary the firing off of another unattached analyser occurs, no fastening to the first free link occurs in the way which has just been described. Instead the first free analyser to have fired off will now be displaced from the link on which it was placed (or provisionally attached) and shifted to the next link which is unoccupied. Meanwhile, the analyser which displaced it will provisionally occupy the first free link. If another fresh analyser fires off after this second one, the process of shifting goes on. The first fresh analyser to have fired will now be shifted to occupy the third free link provisionally, and the second analyser to the second link, which has just been occupied by the first analyser to have fired. The third and last analyser to have fired will now be connected to the first free link. This process of ordering and shifting will continue until the firing off of an analyser already permanently connected to the chain. This event will cause the permanent connexion to the row of those analysers which are provisionally connected to it. Their provisional connexion to their links now becomes permanent.

- (12) When the row is again switched on, these previously free links will also be switched on and behave according to the rules already set forth.

Therefore the factor leading to reinforcement (to use the usual language) is the firing off of an analyser already attached to a row of links. (This is held to underlie the occurrence of the stimulation which the animal was seeking.)

An examination of experimental evidence by Sheffield will elucidate the hypothesis to the reader and will, it is hoped, provide a convincing explanation of it. Sheffield and co-workers (Sheffield & Roby, 1950; Sheffield, Wulff & Backer, 1951) have found that copulation without ejaculation is a primary reinforcing factor in rats or, to put it in another way, possesses reward value which does not diminish with time. They have also found that the taste of saccharine, though non-nutritive, appears to have primary reinforcing properties. These findings constitute a puzzle for those who say that tension reduction or biological need reduction leads to reinforcement. On the present hypothesis the findings form no exception and could have been predicted. As the rat has an unlearned preference for saccharine and aims at copulation without previous accidental experience of it, it is inferred that the analysers signalling a sweet taste (or the various stages of copulation) are connected permanently and innately to the first part of a row of links. This being the case, any analysers fired off previous to these will be connected to the free part of that row of links. Next time the row of links is activated the previously free part will be activated too, with the consequence that an animal will now seek out not only stimulation (or stimulus-configuration) innately attractive to it, but also that stimulation which occurred previous to this stimulation on a past occasion. Thus learning will have taken place in the same manner as it is always supposed to occur on the present hypothesis.

This system converts a temporal series of events into a receptor series. Whenever the system secures any aim, it acquires additional aims in a novel situation. For those analysers, which were touched off previous to the firing off of connected analysers, and were not themselves already connected there, are retained, connected to the chain.

This may be expressed in another way. Learning, in one of its aspects, is an ordering of experience. This feature is expressed in the system by connecting the analysers to an ordering network, which joins them to the free part of a row of links in reverse order as they were touched off. The analysers ordered on the chain will be connected and fixed to it whenever the firing off of an analyser attached to an active row occurs. That is, they will not now be ordered and pushed down any more, but remain stably connected whenever an analyser already connected is touched off and thus switches off its link. The firing off of the analyser of the first unit in the chain would bring this about in the first instance. The system would continually be installing 'new aims'. The attaining of these in a fixed environment will enable the system to reach its final goal (represented by the firing off of the analyser of the first unit) with certainty and will lead to a pattern of activity which is flexibly fixed (by the cues the system is looking for). But this activity will not merely be a repetition of the first random trial. For the system will eliminate blind alleys and false moves, a property of this system which has already been deduced.

It follows that the amount of learning in this system is a function of the amount already learnt, given an environment with a stable composition. A young animal will learn more slowly than an older one. Similarly, an animal with a less varied experience will also be slower. This is pointed out by Hebb (1949). It is predicted by the present theory that the same will hold true for latent learning. Some kind of vicarious trial and error would also be predicted. The animal on this hypothesis is looking for its stimuli.

This view obviates the necessity of distinguishing between primary and secondary reinforcement. The problem of removing the distinction therefore does not arise.

V. QUANTITATIVE CONSIDERATION

So far many of the relations among the elements of the system have been all-or-none in nature with no quantitative or temporal variation. The system set up is, however, complete as it is. It could be given a certain kind of physical interpretation. But to serve as a calculus from which to predict animal behaviour these relations will be postulated to vary with time and in quantity.

Let us formulate the relations in the system in this way:

- (A) The higher the activation of the internal medium, the higher the activation of the first link (5a).
- (B) The higher the activation of the first link, the higher the activation of the other links (6a).
- (C) The higher the activation of the links, the higher the activation of the effector system (1a).

The system would thus act with greater intensity and speed with increased 'need'. If we wish to give a neurological interpretation to the system, intensity can be thought of as frequency of firing along the connexions which mediate the relations between the elements.

- (D) All the consequences of the touching off of an analyser already connected to the chain will increase with the following:
 - (a) the amount of firing from the analyser;
 - (b) the degree of activation of the link switched off.

Therefore, (i) the length of the refractory period (a state which gradually returns to normal) in the link will vary with these factors (4a), and (ii) the threshold of a link's activation

by its predecessor will decrease with the amount of firing from the analyser of the predecessor and the degree of activation of the predecessor and the number of times the predecessor has been switched off by its attached analyser, following the link.

- (E) A link will be unexcitable by its predecessor unless it has an analyser attached. Its threshold will then vary as stated mainly in D(i) and F(13). (The concept of threshold is here used in a quasi-physiological sense.) The actual amount of activation in a link will be a function of the amount of activation of the link activating it and its own threshold.
- (F) A rise in this threshold of the link for activation will occur when the next (preceding) link is varying output. The rise will increase with the length of the period of output by the variation of the next link (13).

This will occur when the feed back required to switch off the next link does not arrive immediately. The threshold will rise with time until the link cannot be activated by the next (preceding) link (14).

- (G) Both these effects of lowering and raising the threshold will fade out with time, leading to the phenomena of forgetting and spontaneous recovery (15).

This statement of the relations in the system as continuously variable gives the theory a power of quantitative prediction. Unfortunately, within the limits of a single paper, some only of the empirical consequences can be put forward.

Massed learning will be less effective than spaced learning, but massed extinction more effective than spaced extinction (see especially section D).

Furthermore, if we agree that the link which gains control of output is always the one with a lower threshold (this is explained later), this will lead to the selection in a choice situation of the most often rewarded habit and one which has been acquired under the greatest need (see D).

Also, these rules will lead the system to select the most constant cues in the environment. Kinaesthetic cues are therefore ordinarily of minor importance except when they are generalized, but distant cues are more important because of their relatively constant nature.

One of the consequences of the hypothesis which it is now possible to draw is that extinction and reinforcement of a habit (or response) can occur without its performance. The application of the theory in this respect will be made clearer if we use it to interpret a study of extinction by Seward & Levy (1949). In this two groups of rats, E and C, ran down an elevated pathway from a starting platform to a goal platform for a food reward. After some training each rat in group E was placed on the goal platform with no food on it. The C group was identically treated except that it was placed on a strange platform. 'Five such treatments were given. . . . On the following day all rats were given extinction trials to a criterion of two successive refusals to leave platform A (the starting platform) within three minutes.' 'Group E reached the criterion in a mean of 3.12 trials, group C in 8.25; the difference was significant at the 0.01 level.'

During the learning trials, it is assumed, a row of links becomes attached to the analysers which fired off before the rat found food. Nearest on the row to the analysers fired off in the presence of food would be analysers firing off in the presence of the goal platform. When the rat finds itself on the empty goal platform in a hungry state the appropriate link (or links) are switched off and the next (preceding) 'food' link begins to vary output without being switched off. This increases the activation threshold of the 'goal platform' link according to paragraph F in this section. Therefore the links which are activated through

this link will also be activated to a lesser degree. Hence the 'habit' will run off at a decreased speed (section B and C) and show extinction with repetition of this procedure. A habit can thus be weakened without actually having been elicited.

VI. ANALYSERS AND OUTPUT

The hypothesis put forward does not claim to give an explanation of the way the total available information is sorted. It takes such things as the perception of configurational properties as given. What it does try to explain is how information influences the actual and future performance of the animal. If one were to construct a machine model of the system, any simple device which delivered a pulse when set off could be equated with an analyser as defined in the system. Equally well, a most complex device could be used. As long as we have a device which is set off only by a specific feature or group of features in the environment it can be used as an analyser in the system. The system as put forward can, however, account for certain characteristics of perception. The analyser and link to which it is connected interact, in such a way that a firing off of the analyser switches off a link (a rule already made).

- (16) Some of the excitation in a link is transmitted to the analyser, increasing with the number of times the analyser has switched off the link, thus lowering the analyser's threshold for firing accordingly.

The analysers have the observed property of firing off more readily the more frequently they have already been fired. Secondly, they also fire off more readily if the chain to which they are attached is activated. That is, the animal or human will tend to see more readily that for which it is looking. By 'more readily' is meant 'on less complete information than that which is necessary to fire the analyser off when these conditions of experience and motivation are absent' (Fig. 3). This way can be deduced when we consider that the

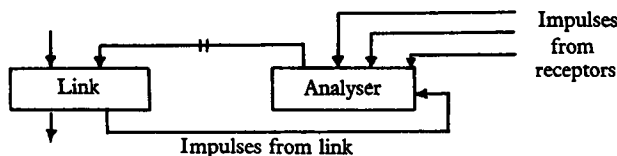


Fig. 3. *The relations between analyser and link.* The impulses from link and receptors additively cause firing off of an analyser. The activation of the link is a function of the frequency of past firings off of the analyser attached to it, and the degree of activation by the internal medium or preceding link. Therefore motivation and experience will influence perception. For key see Fig. 1.

excitation in a link is a function of the excitation of the previous link and the threshold of the link itself. The threshold of the link itself is a function of the number of times the firing off of the attached analyser has occurred. If we treat the impulses from the link to the analyser and the incoming impulses to the analyser as additively causing the firing of the analyser, then it follows that the more frequently the analyser has been fired off (lowering the threshold of the link) and/or the greater the excitation of the link by previous links, the fewer incoming impulses are necessary to fire it off (see Fig. 3). Thus the influence of experience and motivation is explained by the hypothesis. It can be deduced that an animal in a high state of need will eat things which it previously would not have regarded as food, and that it will indulge in 'vacuum activity' (to use Tinbergen's phrase (1951)). Frequently experienced figures will tend to be 'completed'. Hungry men will tend to see

the environment in terms of food. Ambiguous information will be 'interpreted' in accordance with need and experience.

- (17) The output which occurred just before the firing off of an analyser fixed to a link will be there when the link is activated again.

If in searching for a certain station on the wireless one switches off as soon as one has found it, the next time one switches on, one will not have to search again, unless it has shifted.

VII. CONFLICT AND REPRESSION

Though the hypothesis advanced in the previous pages is capable of explaining the learning and performance of a single habit, it must be expanded so that it may be applied to situations in which there is a choice. Let us therefore assume that there are many chains, with the properties described in a system, all of which may control output. No further rule would need to be incorporated if all these were assumed to activate output in turn. But sometimes the system may be confronted with a choice.

- (18) The rule which is therefore added is that if there are two links competing for the same output, the one with a higher rate of firing will secure output.

Now the rate of firing in an activated link has already been made to depend on the degree of activation of the link activating it and the threshold of the link being activated. One of the factors affecting the threshold is the temporary rise in threshold (the refractory period) in a link after the firing off of the attached analyser. Therefore, if an animal is trained equally on two habits of equal length and equal reward, and then allowed to choose between them on closely spaced successive trials, then it will alternate regularly between them. This deduction is confirmed by the experimental work of Dennis (1939) and Heathers (1940).

Hull would, of course, predict the same (from the postulates concerning reactive inhibition). On the other hand, he would predict turn alternation, whereas the present theory in the usual situation demands what might be called stimulus, place or goal alternation. The refractory period of a link is due to the firing off of the attached analyser. This leads to a temporary weakening of the 'attractiveness' of those parts of the environment which have fired this analyser. An experiment performed by Montgomery (1952) to test these alternative possibilities supports unequivocally the deduction from the present hypothesis.

The slower firing link will still give rise to output by varying effectors which the fastest firing link is not varying. It will go on varying output in this way until its attached analyser is fired off. Not being able to use all the possible effectors, it will keep active for a longer time than if it could control them entirely. This consequence of the hypothesis may be used to explain psychosomatic symptoms. Let us take repressed anger. It is assumed that a part of the output of the innate anger unit is fixed (at least as far as the autonomic part is concerned). If angry behaviour is unrepressed, the firing off of an attached analyser switches off the unit and the somatic reaction is transient. This is as would be predicted. But where angry behaviour does not occur when the anger unit is activated, because of faster-firing units which control most of the effectors, it will still bring about an autonomic anger reaction. But this is not transient. It often assumes an almost chronic character. Why the repressed 'affect' should differ in this way from the

expressed is left a puzzle on most theories. On the present hypothesis the answer is quite simple. The unit persists in activity until the component analyser is fired off. In the case of repression of output, it will not be. Hence the persistence, hence the ulcers.

Other kinds of behaviour resulting from conflict would also be predicted. Restlessness, oscillation between alternatives, would be expected under some conditions. In the complete system set up, many rows of links will be in varying degrees of activity. Those in which activity is strongest will determine behaviour.

For example, it has been demonstrated by Hull (1951) and Leeper (1935) that rats can be taught to take one path to water when thirsty and another to food when hungry. Hull explained this by postulating two diverse persistent stimuli, characteristic of each drive, separately conditioned to which the animal would learn to make a different response. Kendler (1946), however, trained rats in a simple T-maze when they were simultaneously hungry and thirsty. There was water in one goal box and food in the other. All animals had equal opportunity to explore both goal boxes. In the test series the rats were made either hungry or thirsty, not both. They were able to make the appropriate choice. This makes a difficulty for Hull. There was only a single pattern of drive stimuli during training, generated by the state of being simultaneously hungry and thirsty. The supposition that rats learn to respond differentially to diverse patterns of drive stimuli in making the choice is made unlikely.

The present hypothesis, on the other hand, presents another way of looking at this evidence. There are two rows of links, one with analysers (presumably in the mouth and stomach, as suggested above) which fire off when food is ingested, and the other when the water is ingested. These analysers are attached to the first link, which is excited by certain changes occurring around it. The one to which the 'food' analyser is innately attached is sensitive to changes occurring when there is a nutritional deficit, the other to which the 'drink' analyser is attached, is excited when there is a water shortage. Now when either or both these links are excited, and the animal is thrown into activity, many analysers unattached to either of these two rows of links will be fired off. If, say, the already attached 'drink' is fired off immediately after these, they will be connected to the links following this attached 'drink' analyser, and not the row of links following the other innately attached 'food' analyser. Next time the link to which the innately connected 'drink' analyser is connected is excited by the appropriate chemical change, the row of links following it will also be excited. These will now have attached to them the analysers which were fired off last time before the innately attached 'drink' analyser, whereas the row of links to which the 'food' analyser is fixed has not. (This hunger-excited row of links may also have some analysers attached to it if some fired off prior to the finding of food.) Therefore when the animal is thirsty, it will begin to look sequentially for those stimuli which occurred prior to its finding water. The same of course applies, *mutatis mutandis*, when it is hungry. Therefore the animal will select that sequence which when it was 'hungry' led to a 'food' result when it is hungry again, on account of the mechanism outlined. It clearly does not make a difference to this ability whether the animal was thirsty or not when it was hungry and found food.

The firing off of an attached analyser can occur to a link even though it is not determining activity, as follows from the basic rules of the system. The firing off of an attached analyser varies its consequences according to the level of activation of the links in which it occurs. Therefore latent learning would be less efficient. The firing off of an attached

analyser according to the hypothesis, is responsible for 'reinforcement'. Without the firing off of an attached analyser no learning will take place. Thus it is predicted that if an animal is placed in a maze hungry, and its physiological deficiency is artificially corrected in the goal box, this need reduction will not act as 'reward'. For what leads to learning is the touching off of analysers which switch off activity in a link. Thus the taste of saccharine acts as a reward, whereas glucose, untasted and unfelt in the stomach, it is predicted, will not.

VIII. SUMMARY

A hypothesis to explain the phenomena of appetitive behaviour has been put forward. This hypothesis is a formal system which is given such an interpretation that propositions concerning appetitive animal behaviour follow from it. It can equally well be given other types of interpretation. For instance, an electro-mechanical learning and reasoning machine has been made by the writer embodying the system (Deutsch, 1954). A stimulus shuts off activity and does not initiate it. The initiation of activity is attributed to centres which are affected by physical states within the body, without the mediation of afferent pathways. Evidence concerning physical needs and instinctive activities is shown to fit such a view.

To account for sequential activities a network is suggested, in which a particular physical state selects a series of receptors which will switch off various types of activity in turn. An explanation of the elimination of blind alleys and superfluous moves is given in terms of the characteristics of this network.

Learning is viewed as a conversion of temporarily successive events into receptor series, arranged in that order in which stimulation occurred. This series may be maintained at the end of another receptor series, under certain simple conditions. 'Reinforcement', according to the hypothesis, is due to the occurrence of that stimulation which the system was selecting. The distinction between primary and secondary reinforcement is thus rendered superfluous. This view is applied to recent evidence on reward. Deductions concerning the role of experience and motivation in perception are also made.

Conflict and choice situations are viewed as the simultaneous operation of many such systems. Since the selection of a particular sequence of activity occurs by and through the units underlying the goals of the organism, some experimental evidence on the selection of habits by their 'anticipated result' is explained.

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