

Emotions in the Function of Heuristics

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EMOTIONS IN THE FUNCTION OF HEURISTICS

1. Problem and Procedure

One of the most important characteristics of creative thought is that it consists of two principal distinguishable phases involving, respectively, the discovery of a principle and its application, the inception of an intention and its fulfillment, the formation of a hypothesis (version) and its verification, or the finding of a preliminary, "functional" solution and the "final" solution (3, 4). Almost all investigators have noted that the analysis of the first phase of the total process is the central (and, at the same time, the most difficult) task in the psychological study of thought.

Attempts have been made to link this phase of creative thought to affective, emotional processes: "A thought is not itself generated from another thought," wrote Vygotskiy, "but from the motivational sphere of our consciousness, which comprises our dispositions and needs, our interests and impulses, our affects and emotions" (2, p. 379).

The purpose of the present investigation was to elucidate certain relationships between thought and emotional processes

during the phase of conception of a plan for solution, the discovery of a basic principle, etc.

The mental work of the subjects involved the solution of complex chess problems (exercises in which mate was to be achieved in two or three moves). The main indicator of states of emotional activation was the galvanic skin reflex (GSR), a choice that requires some justification.

The solution of chess problems is a typical example of creative thought. A solution is not found immediately but usually requires the rejection of some trivial possibilities; it can quite nicely be divided into two phases: the discovery of the basic "idea of the solution" (evaluations of position) and its verification (checking out of alternatives). The question of objective indicators of emotional activation is more complicated. In characterizing these states, we include them in a broader class of active states. Emotions have now been linked with the activity of the reticular formation ("activation theory of emotions" [12]). The GSR, whose central nervous mechanism is evidently associated with the reticular formation, is also an index of emotional activation.

The view that the GSR is associated directly with emotional activation is disputable. An analysis of various psychological theories of the GSR (affective theory, emotional theory, theory of levels of consciousness) shows that the different terms in these theories often refer to similar phenomena. For example, a distinction between "activity" and "attention," "emotions" and "affective processes," or "affectivity" and "level of consciousness" is hardly warranted.

In any case, if our analysis is restricted to the relationship between the GSR and intellectual activity, two interpretations of the reflex are possible: it is (1) an indicator of emotion, or (2) an indicator of "stress." "The psychogalvanic reflex in intellectual activity," writes Woodworth, "is analogous to the muscular stress accompanying mental effort" (1, p. 691). However, the mutual incompatibility of these interpretations seems questionable to us: there is no sufficiently convincing evidence that "stress" can be unemotional if the category of emotions

is limited merely to those emotions recognized as such. Evidence in support of the first interpretation is provided primarily by studies of "free associations" that show that when words associated with an affective complex of the subject are uttered, a GSR is evoked.

A discussion of the relationship between fluctuations in skin resistance and mental processes is complicated by the lack of a sufficiently differentiated interpretation of the diverse characteristics of the same phenomenon — for example, relatively slow fluctuations in skin resistance, rapid decreases in skin resistance (i.e., the GSR in the strict sense) — and by the difficulty in correlating data from different experiments. Nevertheless, at the present stage of our understanding of the problem, it can be assumed that a decrease in skin resistance due to a subjective state that the subject, in a verbal account, categorizes as emotional can be regarded as an indicator of an express state of emotional activation.

An experiment was set up as follows. The subject was requested to solve a chess problem while reasoning aloud (in the main trials). The verbal reasoning was tape-recorded and then carefully analyzed. The time limit for solution was 30 minutes. During deliberation, the pieces were not to be moved. After a definitive solution to the problem had been found, the subject was to say, "The problem is solved." Two first-class chess players participated in the experiment. This level of skill was chosen because the solution to the problems used in the trials was both accessible to first-class players and, at the same time, difficult for them.

During the experiment the subject was asked to sit as quietly as possible. The skin resistance of the subject (palm) was recorded continuously before presenting the chess position, during deliberation on the problem, and for some time after a solution had been found. Type ERR-09 automatic electronic balancing ink recorders were used to record skin resistance. The Feré effect was recorded using the method developed by E. N. Sokolov (11), and resistance scales from 0 to 200k ohms were used. A time-marker was attached to the potentiometer

tape and was synchronized with a sound signal recorded on the tape of the same recorder on which the subject's verbal reasoning was recorded. As a result, we obtained a record of the subject's verbal reasoning with marks indicating time intervals and were able to correlate the fluctuations in the GSR directly with the actual steps in the problem-solving process in terms of time.

After the experiment, the subject gave a detailed, written account of his emotional states and of the problem-solving process.

The use of the GSR gives rise to one peculiar methodological problem, which, however, is important for an interpretation of the phenomenon under investigation. This is the question of time correlates between the recorded reaction and the appearance of an actual state of activation, i.e., the GSR has a long latency period — at least 1.5 seconds. Preliminary experiments run on the subjects had shown that a GSR always appeared in the subject 1.5 seconds after application of an unexpected, indifferent stimulus. This led us to accept the following interpretation: An event evoking a state of emotional activation, as manifested by the appearance of a GSR, can be considered to be the cause of this state when, and only when, the GSR appears no sooner than 1.5 seconds after stimulation. In all cases, when the latency period is less than 1.5 seconds, the GSR can be regarded as an indicator of a state occurring before the event in question, i.e., preceding it.

2. General Dynamics of Skin Resistance During the Solution of Mental Problems

The background recording preceding problem-solving activity was varied. If the subject was excited or awaited presentation of the problem with some agitation, the background curve consisted of "chaotic" oscillations of varying amplitude, and the general tendency of the curve was toward decreasing skin resistance. When the subject was calm, the background recording was smooth, with a tendency toward increasing resis-

tance. If the subject was tense before the experiment, the experimenter attempted to relieve tension by asking the subject not to think of the imminent problem and to "shut himself off" from the surroundings. The main sessions were run only after we were certain that the subject was in a relatively calm state before presentation of the problem.

As the experiment showed, the skin resistance curve had varying appearances for different stages in the solution of the same problem or for solutions of different problems: it either was relatively even, with a tendency toward a rising resistance; consisted of a series of small-amplitude oscillations; or, finally, exhibited sharp and distinct fluctuations in the GSR (e.g., decreases in skin resistance) against a relatively calm background. As a rule the solution of complex problems was accompanied by these types of change in different combinations. The sharp decrease in skin resistance was subjected to a special analysis.

From previously obtained evidence it may be assumed that sharp decreases in skin resistance are associated with "urgent" emotional states arising in the subject during problem-solving. Since there are disagreements in the literature concerning the psychological significance of the GSR (20), we conducted special experiments to determine more precisely the psychological role of this reflex in problem-solving. The following procedure was used. The subject was instructed to press a button, on which his finger rested, at the moment he became distinctly aware of emotional excitation. This provisional signal was recorded on the instrument tape. Experiments run with such an autocontrol showed a strict correspondence between sharp changes in the GSR and the moment of application of the signal by the subject (Fig. 1). No case was recorded in which this signal was given without a considerable fall in skin resistance. It was found that the subject gave the signal after the GSR began to change. Verbal accounts after the experiment also showed a correlation between the appearance of sharp changes in skin resistance and the emotional states of the subject. Thus these data confirmed that under the given conditions, a decrease

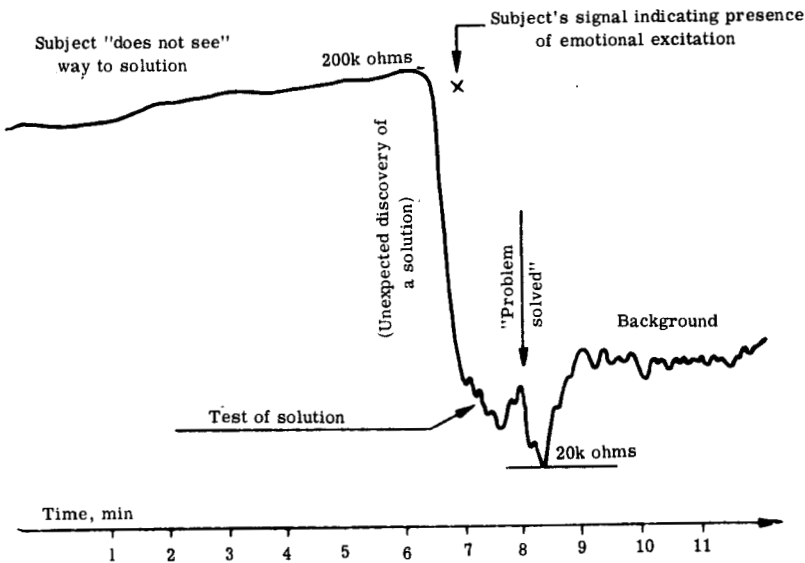


Fig. 1. Relationship between the decrease in skin resistance and the signal denoting the appearance of a state of emotional activation

in skin resistance was an indicator of emotional activation. We should point out that at this stage of the investigation we shall not attempt to provide a qualitative characterization of emotional states.

In the verbal account given after the experiment, the subjects usually reported that emotional states arose at the moment when the first phase of problem-solving was initiated ("Suddenly I discerned a previously unnoticed course of action," "a new idea," "I hit upon an idea for solution," "It became clear," etc.). It

is seen that even the verbal accounts elucidate, albeit in very general form, the circumstance that the moment at which states of emotional activation can appear is confined to critical points in the process of problem-solving and to the discovery of a new principle of action or new direction of search during the course of mental activity.

Different types of chess problems are solved in different ways. In solving some, activity is concentrated on finding the "idea" of a problem, whereas in others, technical deliberations on alternatives predominate. It was found that the different types of mental activity (primarily the predominance of search for an "idea" or technical deliberations on alternatives) are reflected in the characteristics of the skin resistance curve. If the general pattern of solution is clear to the subject, and if he is confident from the outset that he will solve the problem, the decreases in skin resistance are minimal. On the other hand, these decreases are especially pronounced in solving problems in which the search for the basic idea of the solution is most elaborate. These data are direct evidence of a correlation between states of emotional activation and the "creative" aspect of intellectual activity.

Our principal experiments involved correlating the dynamics of the GSR and the verbal reasoning of the subject in solving the problem with the precise time relationship between the recorded parameters. To assess the skin resistance curves, cases in which the decrease in resistance was 3k ohms or more were considered. On the basis of this criterion, 68 cases, involving the solution of 11 different problems, were selected. An analysis of the data obtained in these experiments also points up the correlation between a state of emotional activation and the discovery of a new principle of action during the course of mental activity. At the same time, it proved possible to elaborate a more differentiated analysis of the actual relationship between a state of emotional activation and the discovery of a principle of action for problem-solving, as well as the structure of the problem-solving process as a whole.

3. Emotional Activation and Formulation of an Initial Solution to a Problem

Various characteristics of verbal reasoning were distinguished, and the state of emotional activation was examined specifically with reference to them.

Time relationships between the beginning of a decrease in skin resistance and the subject's calling of a move linked to the solution of the problem or to the direction of further search.

This characteristic applies to 38 cases (of the 68 selected). The time interval between the GSR and the calling of a move by the subject varied between 0 and +12 seconds (+4 seconds average). There was no case in which the GSR might have begun after the subject called a move. The GSR began to change simultaneously with the calling of a move in only 7 of the 38 cases. In the other 31, the shift in the GSR set in before a move was called.

On the basis of what has been said above concerning the latency period of the GSR, it may be assumed that cases in which the GSR shift begins simultaneously with the calling of a move are to be regarded as cases in which a state of emotional activation precedes verbal designation of a specific move.

Thus, if one considers a characteristic of verbal reasoning such as the calling of a move associated with a principle of problem-solving or the direction of further search, it becomes apparent that a state of emotional activation always precedes the calling of a decisive move. Such a state is therefore not simply "confined" to the designation of a new principle of action, but regularly precedes it.

Time relationships between the beginning of a change in the GSR and exclamatory verbal manifestations.

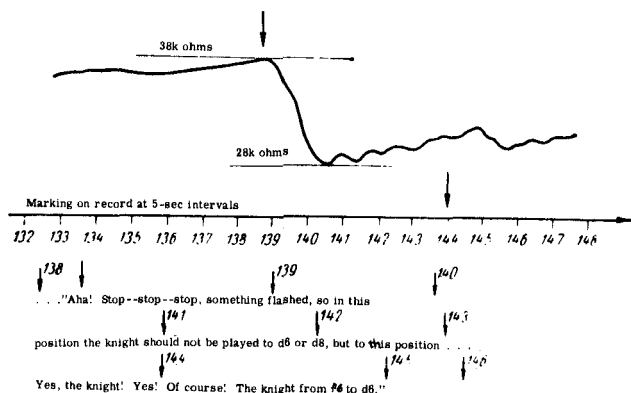
A total of 22 cases of emotional exclamations (Aha!, Oi!, etc.) were recorded. The time interval between the beginning of the GSR and verbal interjections varied from -1.8 to +1.5. A 1.0-1.5-second delay in the GSR was the most typical. Thus, the GSR might be retarded with respect to the type of verbal

reactions described, but this delay did not exceed the latency period of the GSR (with the exception of two cases). From what has been presented above, it may be affirmed that the appearance of a state of emotional activation almost simultaneously with the utterance of interjections is typical. In other words, it can be said that a state of emotional activation is often indicated by the utterance of interjections and a decrease in skin resistance, but the second change has a greater "inertia" and hence is delayed.

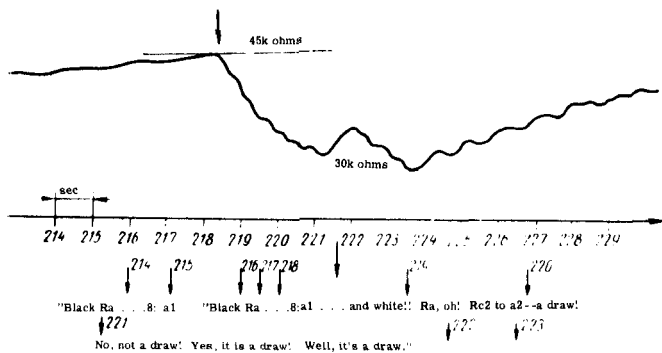
The interjections themselves, as well as the above-mentioned indices of the GSR, as a rule preceded by several seconds the calling of a move representing a solution to the problem or a new direction for further search. In such cases the verbal utterances following an emotional interjection had a very characteristic content: a self-halting signal (stop-stop) in three cases; sometimes an utterance reflecting the approach of an as-yet-unrecognized idea (so-so-so-so, there-there-there-there, of course) in eight cases; the confirmation of an as-yet-unclear result of search (something flashed, I think I found it, I think I've got it) in six cases; and sometimes doubt (a . . . a . . . or not a?) or the need to test (let's try it, that's interesting) in three cases. The subject was able to call a concrete move almost immediately in only two cases.

Verbal activity in the interval between the appearance of a state of emotional activity and the calling of a concrete move is evidence that the search is continuing (Fig. 2a). Thus, emotional activation occurs in anticipation of a principle of action; such a state is, so to speak, associated with a "feeling of being close to a solution."

It is interesting to note that even the changes in skin resistance are of a different order (Fig. 2b): as the curve falls, they seem to consist of discrete jumps or a series of consecutive shifts reflecting a buildup or intensification of the state of activation. This type of curve greatly resembled the curve in experiments for determining the latency periods of an orienting reflex as it appeared before the application of some stimulus, at a time when the subject was "in a state of tension or expected another unpleasant stimulus" (from the verbal account).



a



b

Fig. 2. Time relationships between a shift in skin resistance and the verbal reasoning of the subject: (a) in formulating a principle of action; (b) in evaluating the results of search

Solution of problem:

- 1) Rc3-f3 +! Kif1-q2! 2) Rf3-b3! Ka2-c3 + 3) Kid1-c1! Rab:a1 4) Rb3-b2 + Ki ~ 5) Rb2-a2! Kc3:a2 + 6) Kic1-b2!! 7) Kib2:a1

Solution of problem:

- 1) Kia1-b1 Rc2:c1 + 2) Kib1:c1 Ra5:a4 3) Kic1-d1! Ra4-d4 + 4) Kid1-e2! Rd4-e4 + 5) Kie2-f3 Re4-e8 6) Kb8:d7 Re8-q8 7) Kd7-f6 Rq8:q7 8) Kif3-q4 Kic3-d4 9) Kiq4:q5 Kid4-e5 10) Kiq5-h6! Kie5:f6.

Time relationships between the beginning of a change in the GSR and the verbal confirmation of an as-yet-obscurer result of search.

In several cases the subject's calling of a concrete move was preceded by verbal assessments such as "something flashed" or "I found something." Six such cases were recorded; in four of these, the GSR appeared prior to the verbal assessment; in one case, simultaneously with it; and in one case, with a delay of 0.5 second. Consequently, a state of emotional activation ("a feeling of being close to a solution") precedes even the utterance of an indefinite verbal assessment.

Time relationships between the beginning of a GSR and an evaluation by the subject of the next tentative solution.

There were 25 cases in which the GSR was linked with the subject's evaluation of the next tentative solution rather than with the delimitation of a direction for further search.

The GSR was delayed with respect to the moment of utterance of verbal assessments ("mate," "no that's wrong," etc.) in only three cases, but this delay did not exceed the latency period of the GSR. In 17 cases, the GSR preceded verbal assessment. This advance was especially obvious in those cases in which the subject arrived at a conclusion only gradually in the evaluation and testing of alternatives; he was still not convinced of the correctness of the evaluation, his speech reflected some doubt, and the skin resistance had already begun to decrease (see Fig. 2b).

Time relationships between the beginning of a GSR and the calling of a definitive (objectively accurate) solution to the problem.

In all cases, when the subject found a definitive solution to the problem that was also objectively correct, the fall in skin resistance preceded the calling of a definitive solution by several seconds. For example, "Then we will move the pawn, oh, . . . Oh! q3 to q4. There is the king; where can I put the king? Shall I sacrifice the bishop, or . . . or . . . or what? or concede! Well, there you are! I guess the game and position are won!" The GSR began at the moment the word "or" (underlined in the

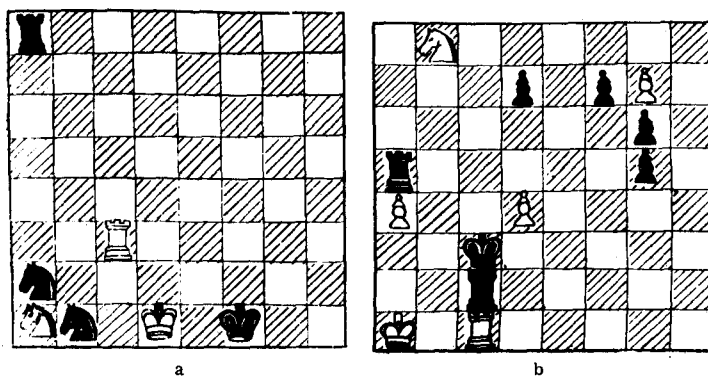


Fig. 3. Problems presented to the subject for solution

text) was uttered, and preceded the final solution by ten seconds, when the subject was satisfied that the problem was solved and uttered the words "I guess the game and position are lost."

Thus a differentiated analysis of the relationships between states of emotional activation and the various components of verbal reasoning show that states of emotional activation are, as a rule, preceded by the verbal designation of the principle of the problem's solution and of the direction of further searches, and assessment of the next tentative solution and the designation of a definitive solution.

4. Change in Activity After Appearance of a State of Emotional Activation

A special analysis of the data was undertaken to elucidate the function of emotional states in the continued search for a solution to a problem. Let us examine the data on the basis of concrete examples.

The subject solved the problem illustrated in Fig. 3a. During the course of deliberation, a moment of sharp decrease in skin resistance clearly appeared (at the 19th minute). In the

verbal account, this moment was when "it became clear" to the subject or when "an idea for a solution" appeared. In his reasoning, the subject called the move 3Rc2—a2, with which he linked the solution to the problem. It should be emphasized that the subject called the solution only on the 30th minute, although a state of clarity ("I think I found a solution") was reached as early as the 19th minute (see Fig. 4a). If the problem-solving process is regarded as a process of removing uncertainty, one can refer to a primary, preliminary form of removal of such uncertainty, associated with the appearance of emotion (the subject becomes convinced of the correctness of his proposal, although it is not yet objectively certain that it is correct). The appearance of this specific state, which, as we shall see later, considerably alters the structure of subsequent activity, can be provisionally called an "emotional solution to a problem."

The decrease in skin resistance in the case described was as much as 14k ohms and contrasted sharply with the background (Fig. 4a). This reaction, like those examined above, preceded by four seconds the calling of the move with which the subject hypothetically linked a solution. Hence we may refer to a specific emotional anticipation of a verbalized intention.

Thus an emotional reaction twice preceded the verbal expression of a solution, the calling of a definitive final solution, and the statement of a probable hypothesis. The first anticipation is measured in minutes (sometimes tens of minutes), and the second in seconds.

The moment when an "emotional solution" (1) appeared marked the division of the entire problem-solving process into two qualitatively different phases. The structural change in the process after appearance of an emotional solution to the problem is manifested by quite distinct indices. To begin with, the domain of subsequent search is quite strictly delimited. Activity becomes more directed, and the subject examines only the possibilities of certain pieces after 2Ra8—d8. Prior moves are repeated in a strictly determinate order. The total

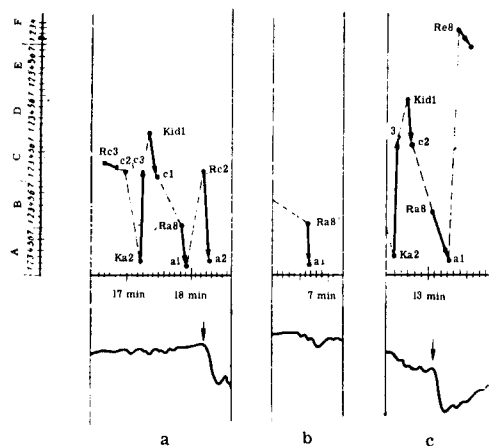


Fig. 4. Relationship between the verbal reasoning and the skin resistance record. Successive calling of moves by the subject presented graphically: divisions on y axis correspond to the squares on the chessboard; each move of a piece from one square to another is indicated with an arrow uniting the points corresponding to the initial and final position of the piece; x axis — time intervals. Below — skin resistance curve: a — moment of emotional solution to the problem; b and c — accumulation of the emotional coloring of the move Ra8—a1

number of move sequences examined by the subject decreases, and the scope of exploratory activity diminishes. These peculiarities are evident in Fig. 5, which presents "game trees" before and after an emotional solution. Besides changes in the domain, direction, and scope of search, the very nature of the exploratory act itself changes. This is initially manifested by elimination of review of certain elements of the situation, in which the same elements of the situation are placed in new interrelationships. This is true, for example, of the moves 1. Rc2—Kic3, 2. Kic1. In the first step the move Rc2 is examined twice in different systems of interrelationships (likewise for the move Rb3, etc.). As had been demonstrated previously

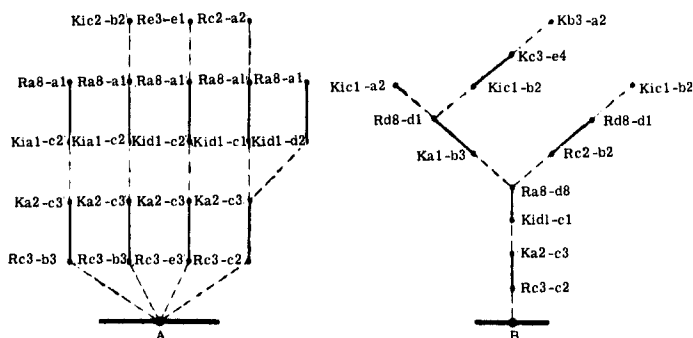


Fig. 5. Game tree: A — before an emotional solution to the problem; B — after emotional solution to the problem. "First let's see how it is. We stopped at a position — then the black rook declared check to the white king at d4, on 4 so? There you are . . . Aha! There it is! The white king, the white king, let's check it! Here it is, here's the white king c oh! d1 goes to e2, right! The white king goes to e2."

(9, 10), the tactic of review of the same elements of a situation reflects the development of the significance of the same elements of a situation for the player (significances are also developed by review). Consequently, elimination of the tactic of review can be interpreted as the cessation of the development of significances (of at least some of the elements) in the second phase of problem-solving. The patterns described — delimitation of a domain of search, reduction of its scope, the setting of a direction of investigation, and the change in the nature of heuristic acts after an emotional solution to a problem — are evidence that emotions fulfill a definite regulatory function.

In the first phase of search (before an emotional solution), certain important patterns were established. It was found that at a certain stage of search in one of the attempts the move 2. . . Ra8—a1 appeared with a distinct emotional coloring (and also with a brief anticipation, see Fig. 4c). The move 2. . . Ra8

—a1 directly preceded the move Rc2—a2, which in the alternative then chosen was critical for a solution of the problem.

Although an emotional coloring appeared around the most critical move, the move preceding it appeared without an emotional coloring. Thus this substantiates a shift in emotive areas in the process of problem-solving and a definite heirarchy and priority among them. The existence of one area primes the appearance of another, and in the given case primed an emotional solution to the problem.

In addition to the use of an emotional experience in formulating a hypothesis, an intensification in the emotional coloring of the same move noted in different trials can be observed. The same observation is applicable to the move 2. . . . Ra8—a1, which directly preceded the critical move. On the 7th minute of the problem-solving process, the calling of this move was preceded by a 6k ohm shift in the GSR, while on the 14th minute the calling of the same move was preceded by a 15k ohm shift (Fig. 4b, c). Therefore, the prior emotional coloring of the move was cumulative. Certain conditions relating to the actual generation and formulation of a hypothesis were thus ascertained. These involved the cumulation of emotions and a gradual shift in the emotive area.

In the second phase of problem-solving (after its "emotional solution"), when the correctness of an already formulated hypothesis is tested, the GSR curve had a more quiescent character than during periods of verbal reasoning in the first problem-solving phase. The small-amplitude decreases in skin resistance corresponded to moments that were critical for the hypothesis being checked. The final declaration of a solution to the problem was also preceded by a decrease in skin resistance (change in the GSR with a 0.5-second advance and amplitude of 7k ohm).

In the problem analyzed above, the work of the subject was completed at the stage at which he became definitely convinced of the correctness of a solution that objectively was not correct. But in solving problem No. 2 (Fig. 3b) the subject found an objectively correct solution. In this case an analysis of the

dynamics of the process revealed the same patterns as in the solution of the first problem, although there were certain unique peculiarities.

A stage of emotional solution appeared again in association with the move 4. Kid1—e2. The shift in the GSR preceded the calling of the critical move. The magnitude of the shift was greater than the background variations in resistance. The amplitude of the reaction was greater than in the solution of the first problem. In contrast to the first problem, "an emotional solution" occurred more than once. Before the subject was convinced about the actually correct solution, he had become convinced of the correctness of a solution that actually was not completely accurate, but very nearly so.

Again, a priority in the emotional responses of the subject is noted. Whereas in the first problem an intensification of the emotional coloring of a concrete move was evident, in the second problem there was a transition from the calling of a move without an emotional coloring to the calling of the same move with emotional coloring. Thus the move 1. . . Rc2—c1 was considered twice, the first time without an emotional coloring (on the third attempt), and the second time with an emotional coloring (on the fifth attempt). Between these two attempts the subject tried another move for black. On the sixth attempt another move was again tested for black without emotional coloring, but with a preceding emotional evaluation with respect to the given attempt as a whole. As in problem No. 1, change in the emotional coloring of a move according to its remoteness from the initial situation was noted.

It is interesting to note the coincidence of objectively critical moments for finding a solution to a problem (these moves were designated with exclamation points by the author of the book from which the given problem was taken) and subjectively critical moments such as moves No. 3, 4, and 10, which were accompanied by changes in the GSR.

In verifying a discovered problem-solving principle, the subject in some instances pursued a false course for quite a long time. Such a "digression of search" was also preceded by an

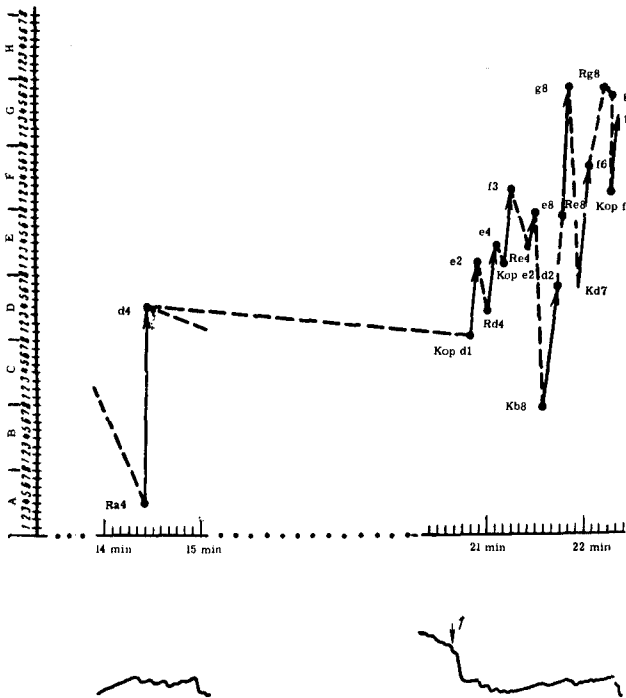


Fig. 6. Reversion of search to an emotionally colored move Ra4—d4. Symbols same as in Fig. 4

emotional change. However, it is important to note the circumstance that after a negative assessment of an unsuccessful course of search, the subject returned not to the initial situation of the problem, but rather to some critical, emotionally colored point. The move 3. Ra4—d4 (Fig. 6) is just such a point.

Thus the heuristic function of emotions evidently consists of the delimitation of some domain that directs not only further exploration into the problem but also the reversion to some definite prior point when a search has led into a disadvantageous situation.

During verification of the hypothesis in the second problem, there were no quiescent periods in the GSR as there were with

respect to the first problem, since during the testing processes points arose that were critical for the hypothesis (consequently, a decrease in the activity of the GSR during testing occurred only when these points did not occur). A change also took place in the GSR prior to the designation of a definitive solution that proved objectively correct. This change was, again, less pronounced than the change that occurred when a basic idea had been discovered (10k ohms).

Thus, an analysis showed that emotional states fulfill various kinds of regulatory functions during problem-solving. At the same time, analysis gave rise to the following question: Are emotional states actually necessary mechanisms within the process of search for a solution to a problem? After all, emotional states occur in cases in which a problem is not solved as well as in those in which the subject finds a correct solution.

5. The Necessity of States of Emotional Activation

In carrying out our experiments there were cases in which the subject had not been able to solve the problem and, in the subsequent account, wrote that he was unable to decide on a solution, felt apathetic and indifferent, etc. The skin resistance in such experiments showed a lack of periods of emotional activity. This phenomenon was especially obvious in one of the subjects who, during the entire series of experiments, was in a state of depression caused by external circumstances. During this time we obtained a flattened GSR, and the subject was unable to solve any of the problems that he evaluated as "difficult" (it is interesting that sometimes the first activation reaction occurred only after the subject had stated that the experiment was finished; here the GSR stood out especially clearly as an indicator of "attitude").

In a special series of experiments, an attempt was made to evoke a state of emotional inactivity artificially in the subject and to trace its effect on the productiveness of his efforts. Of the means tried, the following proved relatively more effective. The subject was given special instructions to present verbally

the problem-solving process as indifferently and monotonously as possible. To carry out these instructions the subject was compelled to suppress emotion in order to maintain an indifferent tone. In three problems of this series flat skin resistance curves were actually obtained, and the problems were evaluated by the subject as difficult and remained unsolved. Sometimes the subject was able to solve "easy" problems even when the GSR curve was flattened, although in at least one case a quite sharp decrease in skin resistance was observed. (2)

In another series of experiments, the subject was given the following instructions: "You must solve the problem presented, and you must solve it with absolute equanimity, without any emotional tension. Bear in mind that we are able to observe your emotional state with the help of instruments, whether you begin to feel agitated or not. As soon as you violate the instructions, we shall stop the experiment at once." In this series of experiments, 13 problems (to mate in three moves) were presented to the subject. In no case was a correct solution found without the prior appearance of a state of emotional activation. Thus, the data obtained indicated that emotional activation is a necessary condition for productive intellectual activity.

This conclusion is also confirmed by the verbal account of the subject: "This damned machine (i.e., the potentiometer) does not let me think." "I can solve only easy problems without emotion; difficult ones, never," "The demand to solve the problem with equanimity keeps me from making a detailed examination of a possible solution."

It is interesting to observe that in this series of experiments the subject attempted to adapt himself to the complicated conditions. This is seen in his resorting to the tactic of guessing a solution without analytic heuristic activity. The subject then began to compete with the instrument, trying to anticipate a change in the GSR. Although the declaration of a hypothetical solution before a GSR was possible in principle, no such guesses were correct.

In some problems the experimenter intentionally broke the conditions established for the experiment, but did not interrupt

the activity of the subject after a GSR had appeared in association with an attempt to guess a solution. Under these conditions, two of four problems were solved by the subject; but in both cases the moment of decrease in skin resistance preceded the declaration of a correct solution.

Subsequent control experiments showed that the mechanism of emotional activation is necessary for carrying out "creative" work, but not intellectual work in general. The subject was requested to carry out operations of addition and subtraction of two- and three-digit numbers to himself, and to count aloud to one hundred. In these cases the GSR curve appeared flattened, with a tendency toward increasing resistance.

6. Discussion of Results

Investigations have shown that there is a quite distinct relationship between states of emotional activation and the discovery of the basic principle of a problem's solution by a subject. The question is how to interpret this relationship.

One possible interpretation is as follows: the subject finds the principle of solution, whereupon a state of emotional activation immediately ensues. The latter is thus the result of a successful solution. A second interpretation, which seems much less obvious, is that states of emotional activation are directly involved in the process of searching for the principle of solution. (3) The fact that states of emotional activation regularly precede the declaration of a principle of solution supports the second hypothesis somewhat. But this suggests the following alternative: either the principle of solution is initially found on a nonverbal level and is then verbalized (so that activation could be an indicator of a discovered, but as yet un-verbalized, principle of solution), or a state of emotional activation precedes and prepares for the discovery of a nonverbalized solution.

An analysis of verbal activity in the interval between the moment of appearance of a state of emotional activation and the verbal declaration of a principle of solution showed that during

this interval the speech of the subject contained no indications that a principle of solution had been found, but only that it had been verbalized. On the contrary, it showed that the subject continued to search for a principle of solution. A state of emotional activation appeared as a kind of nonspecific "stop" signal, as an indication of where what had not yet been found ought to be found; in addition, it appeared as a nonconcretized anticipation of the principle of the solution (or of the final solution). This emotional anticipation of the principle of a solution was termed by us "a feeling of being close to a solution."

Thus, the discovery of the principle of a solution to a problem has two phases: initially, an approximate area is isolated in which the principle of solution can be found; then the principle itself is found. Emotional activation is evidently associated with the first, preliminary phase, which, so to speak, determines the subjective value of a certain direction of search.

The interpretation according to which a state of emotional activation prepares for the discovery of the principle of solution and does not simply precede its verbal expression is also confirmed by the fact that a state of emotional activation directly preceding the formulation of a hypothesis is itself prepared for by preceding states of emotional activation (the above-described phenomena of accumulation of emotions and shifts in the emotive area).

In conclusion, we shall consider the question of the function of states of emotional activation.

P. V. Simonov has recently advanced an interesting hypothesis according to which an emotion is a compensatory mechanism that makes up for a deficit in the information necessary for achieving a goal (9, p. 77). However, in this view of Simonov's, the concepts of "information" (and correspondingly the concepts of "deficit" or "excess" of information) are insufficiently precise. If the concept of "information" is understood in its usual, generally accepted sense, then goal-directed activity can hardly be understood in terms of these concepts alone, abstracted from the meaning or value of information. The stipulation that the author had taken into account the

"concrete value" of information is only formal, since in the work of A. A. Kharkevich (16), to which Simonov refers, the problem of a quantitative evaluation of the value of information had not been solved.

Even if one disregards the insufficient development of quantitative measures for evaluating the value of information and employs this expression in a nonquantitative sense, the question of the function of emotions can be formulated thus: when it becomes necessary to search for information to organize activity, do emotions replace (compensate, according to Simonov) this search, or do they regulate the course of the search? The facts described in the given investigation substantiate the second interpretation: emotions participate in the regulation and control of heuristic activity.

In developing his approach to emotion, Simonov suggested the idea of "mental mutagenesis," in which emotions are directly linked to human creative activity (10). Emotional excitation leads to "the generation of useful noises or mental mutations." This makes it possible to bypass trivial solutions by "correlating traces of real events in improbable, previously unencountered, or extremely seldom encountered combinations." In this context, the question of the function of emotions can be formulated thus: are emotions only a generator of random solutions, or are they primarily a factor in determining the direction of search? The facts presented above support the second point of view.

Our views on the function of emotions acquire special significance in the context of problems of programming, or the solution of intellectual problems by electronic computers. The solution to such problems requires a psychological study of human intellectual activity in order to discriminate mechanisms that regulate the degree of abridgement and the direction of search, i.e., heuristics (9-11). The heuristic approach does not guarantee that a solution to a problem will be found; but without it, it is impossible to solve a certain class of problems. In our investigation we were able to demonstrate the following steps: delimitation of the domain of a search, reduc-

tion in its scope, determination of a direction of investigation, and change in the character of heuristic actions under the influence of evoked emotional activation and the necessity of this activation for productive activity. These facts illustrate that emotions have a heuristic function in the solution of complicated intellectual problems.

In recent years, research into thought processes has been greatly influenced by cybernetics and direct analogies between the work of computers and human thought. However, different approaches to the study of thought in a cybernetic context can be distinguished. One of these, which has recently enjoyed wide application (6-8, 17-19), uses a system of concepts describing the work of a computer ("elementary information processes," "collection of information," "program," "algorithm," etc.) in characterizing thought, thereby pointing up the close similarities between the function of a computer and the function of a human being. Evidence showing that emotions fulfill a heuristic function indicates that this cybernetic approach to the study of thought is not the only possible one, but that there exists another approach, which takes into account, first and foremost, data from study of the uniqueness of human thought as compared with the function of a computer. In this approach, the correlation of the function of a human being with that of a computer is not only the object of research but also a method for ascertaining the peculiarities of human thought. Further study of emotions in their heuristic function is evidently a means of ascertaining one of the specific peculiarities of human intellectual activity.

Notes

1) Here it may be objected that the division of search into two phases is in no way associated with emotional activation, that it is entirely a matter of "discovery of a principle." However, not every formulation of a principle of action leads to a reduction in the area of further search, but only one that is accompanied by emotional coloring (and is experienced subjec-

tively as conviction). To bring this factor into relief, we introduce the expression "emotional solution of a problem."

2) It should be noted that this measure of suppressing emotions did not, however, give a consistent effect. After a few attempts, the subject adapted to the experimental conditions and found a convenient level of loudness in speaking during the course of solution, and the requirement of monotony in speaking ceased to inhibit emotional reactions. As a result, moments at which the skin resistance fell considerably during the process of problem-solving were again noted on the skin resistance record.

3) To use a descriptive comparison, emotions can be likened to evaluations of "hot" and "cold" in the children's game in which a hidden object is sought; the seeker receives these evaluations before the object is found.

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