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AN OBJECTIVE INVESTIGATION OF THE DYNAMICS OF SEMANTIC SYSTEMS

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1

Human consciousness is a system of very intricate semantic connexions, relating to different stages of past experience and constructed on planes of different complexity. At any given moment some of these semantic systems are dominant, while others are pushed into the background and continue to exist as potentials. The objective investigation of this real relationship between actual and potential links of semantic systems, dependent on a number of conditions, continues to be a most important problem, and is as yet far from a satisfactory solution.

This problem is not solved by the investigations of conceptual thinking which are widely practised in psychology and which make use of the methods put forward in their time by Vigotsky (1956) and Goldstein (1948); these methods give a good description of semantic structures available to the subject, but do not allow one to proceed to the analysis of that real correlation between dominant and potential links of these systems, which often remain insufficiently realized by the subject himself, and which do not permit a sufficiently accurate tracing of their dynamics. Nor is this problem solved by the investigation of affective complexes which constitutes the fundamental element of psychoanalysis; the absence of an objective method remains to this day the weak point of psychoanalysis in which the description of the dynamics of meaningful associations is often transformed into a system of unfounded surmises thereby depriving it of the character of a genuinely scientific study. The proposal to make use of motor reactions, in the capacity of objective symptoms of affective complexes, which was put forward by one of us many years ago (Luria, 1932), permitted a considerable step to be taken in this field, but did not yet make it possible to proceed to that objective study of the dynamics of semantic systems which, as before, presents one of the fundamental problems of psychology.

In order to approach the solution of this problem we must consider the use of a number of objective methods, which have been formed from the study of the higher nervous activity of man and which make use of the recording of the involuntarily arising symptoms of dominant semantic systems.

One such method was applied by Schwarz (1948, 1949). Recording the change in light-sensitivity of a dark-adapted eye, resulting from a sudden illumination, she then combined this sudden illumination with the pronouncing by the experimenter of the word 'doktor' (physician); after a few combinations, this word, which up till then had been neutral, began to provoke a conditioned-reflex lowering of the thresholds of light-sensitivity. But, as experiment showed, such a lowering of the thresholds of light-sensitivity *was objectively provoked by the use of a number of other equivalent words too,* and a normal adult subject knew such words as 'vratch' and 'lekar' (both meaning physician) which sound completely different, but which are equivalent to the key word in meaning. Tests carried

* Paper read at a meeting of the British Psychological Society, 19 August 1957.

out to check this showed that words similar in sound but pertaining to a different sense group (e.g. the word 'diktor' (announcer) did not act as equivalent stimuli, and did not provoke a corresponding change in the thresholds of light-sensitivity). However, if the subject was given the appropriate dose of chloral hydrate, and the cortex was put into an inhibitory state—the system of equivalent links changed, and now, the patient being in a drowsy state, the word 'diktor', which is similar in sound (to the key word) began to provoke the same conditioned reflex change in sensitivity, while the synonymous words 'lekar' and 'vrach' lost their character of equivalent stimuli. Analogous tests have been carried out, using different objective indicators (the recording of salivary, galvanic skin and vascular reactions, depression of electrical activity of the brain and of the blood coagulation reactions) by a number of other investigators (Riess, 1940; Krasnogorsky, 1954; Volkova, 1953; Lacey & Smith, 1954; Marushevsky, 1957; Razran, 1949*a*, *b*; Markosyan, 1957; and others).

The facts obtained in these investigations open up new ways for the objective study of the dynamics of semantic systems. They show, first and foremost, that a single verbal stimulus (i.e. the word) provokes in the subjects, not an isolated, clearly delimited reaction, but a definite *system* of connexions, and indicate that this system of links is of a strictly selective nature. They further show that, in a normal adult subject, these dominant links are meaningful links: owing to this, words included in past experience in a system and having the character of synonyms, begin 'on the spot', to provoke the same reaction, while words linked on an outward sound basis are braked and practically inactive. These facts further show that when the cortex is in a state of inhibition, this real correlation of dominant and suppressed links can alter, so that the relatively simpler sound-connexions may become dominant, and the more complex semantic connexions inhibited. Finally, and this is especially important, all the experiments show that *an objective line of investigation of the system of semantic connexions and their dynamics does exist*, and that this method is connected with the alteration in the conditions of the brain's functioning. This shows that the investigator has at his disposal the real possibility of concluding which are the dominant links of the system and how the correlation of these links actually changes with the alteration of the normal conditions.

2

The method which has been used in this study is based on data obtained in the laboratory of E. N. Sokolov (1958) and relating to the study of the components of *orienting reflexes* (Vinogradova & Sokolov, 1957).

As these observations showed, the introduction of any new stimulus (visual, auditory, tactile, etc.) provokes a distinct vascular reaction consisting of *a contraction of the finger blood-vessels and a dilatation of the blood-vessels of the surface of the head.* These vascular reactions are gradually extinguished with protracted repetition of one and the same stimulus, but recur when the stimulus is changed. They intensify when the stimulus is intensified, weaken when the stimulus is lessened, and appear especially distinctly as soon as the weak stimulus (e.g. the sound) approaches threshold intensity, becomes hardly distinguishable and consequently begins to provoke extra active orienting reaction in the subject.

All these indications permit us to evaluate the given changes as a *vascular component of the orienting reflex.* A rapid extinction of the vascular component of the orienting

reflex is observed in the case of the stimulus which is irrelevant for the subject. If, with the help of verbal instruction (for instance by suggesting that the subject press a button in answer to every signal) or with the help of unconditioned reinforcement (a pain or thermic agent) the stimulus is given a signalling meaning, then the tentative reaction to it becomes considerably more stable. It is maintained during 25–40 repetitions of the stimulus, and the extinction occurs when the reaction becomes automatic.

The facts described permit the use of the method of recording the vascular components of the orienting reflex, in the question interesting us in this article—namely the objective study of the structure and dynamics of semantic systems. This was carried out by one of us (Vinogradova) in this study.

The subject, who was sitting in an armchair in a sound-proof room, was given a series of words; each word was pronounced at intervals of 20 to 180 sec. A glass tube was fixed over a finger on the subject's left hand, fitting tightly to the skin of the finger: pneumatic transmission connected it to the recording capsule on the photoplethysmograph. The change in size of the finger blood-vessels was recorded on the film. Similarly, the change in size of the blood-vessels of the head (region art. temporalii superficialis and art. frontalis) was also recorded. A capsule tightly fixed to the temporal region of the skull and attached to a special holder served as receiver.

The first part of our investigation was carried out on ten normal school-children, aged 11–15 years, and on fifteen mentally retarded children of 13–17, attending a special school. The words used in the experiment were spoken aloud by the experimenter as monotonously as possible and at one volume-level. 'Neutral' words were chosen for the experiment, i.e. words which could not provoke any special emotional reaction whatever in the subject.

As observations show, the use of different words provoked, in the normal subjects, at first orienting reactions manifested by the contraction of the finger blood vessels and by the dilatation of the blood-vessels of the head surface,* but after 15–20 different words had been given, this reaction was extinguished and the vascular curve remained on the same level when the words were given. This fade-out of orienting reflexes to any word marked the first stage of the experiment.

Against this background of extinct orienting reactions, a special signalling meaning was given to one word (in the experiments described this word was 'koshka' (cat)). The subject was asked to press a button with his right hand every time he heard this word; on the photographic record the motor reaction of the right hand was registered and also the vascular reaction of the left finger.†

The experiment showed that, in these conditions, *every time the signal word, 'koshka', was given it evoked in a normal subject not only the motor reaction of the hand, but also a steady orienting vascular reaction*, which was maintained for a long time (during 20 to 40 repetitions), whereas the giving of other 'neutral' words provoked neither a motor nor a vascular reaction. Such a distinct isolation of one signal word, evoking a stable vascular reaction, allowed us to begin the main experiment.

The first question before us was the following: is the orienting vascular reaction evoked

* For simplicity of exposition in this part of our report we shall use only one of these indicators—the contraction of the finger blood-vessels. We shall specially examine the relationship of both indicators later.

† Naturally the first thing that was established was that the pressing of the button with the right hand evoked only a momentary occurrence of vascular reaction in the finger of the left hand and had no influence on the vessel reactions in further experiments.

only by the *given* signalling word, or does the same effect extend to a *whole system of words*, and can it be evoked by a number of other verbal stimuli which—*without evoking an open motor reaction*—could however *evoke a vascular reaction*? In the event of such a thing taking place, we would be able to work out objectively *a system of semantic connexions characteristic of a given subject in the circumstances under investigation.*

Observations drawn from corresponding experiments make it possible to answer this question.

If, under the conditions just described, we gave the subject an absolutely neutral word (having nothing in common, either with regard to sense or to sound, with the key word 'koshka' (cat); e.g. 'steklo' (glass), 'karandash' (pencil), 'oblako' (cloud), etc.) we did not get a vascular reaction. If we gave the subject a word connected in meaning to the key word ('kotyonok' (kitten), 'mysh' (mouse), 'zhivotnoye' (animal), 'sobaka' (dog)) *though there was a complete absence of motor reaction, there occurred a distinct contraction of the finger blood-vessels, which pointed to the presence of an orienting reaction.* This gives

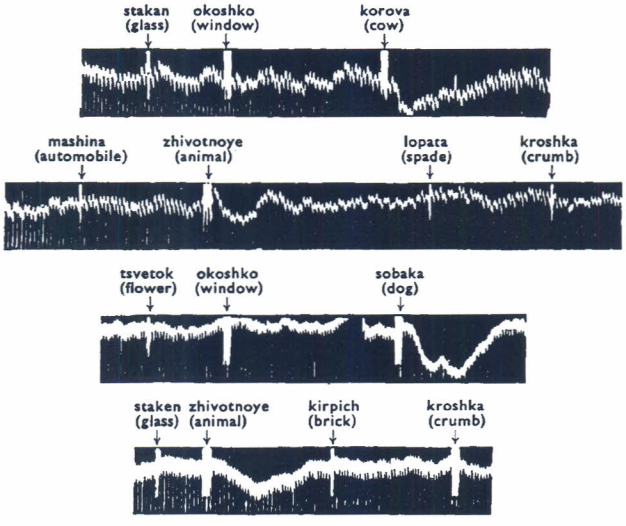

Fig. 1. The nature of the reactions of normal school-children of 11–12 years to word stimuli. Words linked in meaning with the signal word 'koshka' (cat), 'korova' (cow), 'sobaka' (dog), 'zhivotnoye' (animal) evoke reactions; words similar in sound, 'kroshka' (crumb), 'okoshko' (window), have no effect. In the figure the plethysmogram of the finger is recorded. The moment of application of word stimulus is registered by vertical lines. The thin vertical lines are the recording of time in seconds.

us grounds for assuming that the given words were not without significance, for the subject. A heightened orienting reaction to these words can be explained only by the existence of a functional semantic connexion with the basic signal word, formed in the past experience of the subject. This fact was constant, and words having a direct connexion with the signal word provoked a relatively more manifest vascular reaction, whereas words of a general nature, and linked less directly and obviously with the critical word, provoked a less evident vascular reaction. In contrast to this—words not having a sense link with the critical word and bearing only a superficial phonetic resemblance to this word (e.g. 'okoshko' (window), 'kroshka' (crumb)) did not provoke a vascular

reaction, thereby indicating clearly that, in a normal subject, they are not included in his actual system of sense links. Fig. 1 gives examples of the facts described.

These experiments allow us to draw important conclusions. They show that, in evoking an orienting reaction to one word, we bring about, at the same time, *a whole system of meanings*. This can be revealed objectively in those cases where the subject does not display any outwardly manifest voluntary reactions to words pertaining to this system. These experiments further corroborate the fact established earlier, namely that the semantic is the dominant system, while sound resemblances, pertaining to the outward sound aspect of the word, are not included in the dominant system. Finally, the experiments allow us to take a few steps towards the objective analysis of the stability of these connexions, distinguishing the group of words which reveal a closer link with the given key word, from those revealing a more remote link. In this way, we are brought nearer to an objective analysis of the structure of this system of semantic connexions.

On the basis of the experiments carried out we can consequently conclude that the whole semantic system obtained in our 'model' experiment acquires the following structure: in the centre of this structure stands the *key word*, which has a signalling meaning and evokes both a motor and an orienting vascular reaction. This 'nucleus' is surrounded by a whole system of *potential sense-links*, to which pertain words which do not evoke an overt motor response, but which do evoke only an orienting reaction. Finally, outside of this system lie those neutral words which do not evoke any motor or vascular reaction at all. In the normal subject, words not having a semantic connexion with the critical word, but resembling it in sound are also related to these 'extra-systemic' signals.

3

However, the question arises: how is the described semantic system changed when certain disfunctions of the brain are present? To this end experiments were carried out on mentally retarded children suffering from oligophrenia,* in different degrees (debility and imbecility) and being taught in special schools. As previous investigations of the higher nervous activity of these children have shown (Luria, 1956, 1958), under-development of the higher functions of the speech system is characteristic of such children.

Experiments in this series gave results which differed sharply from the above-described experiments with normal school-children.

The system of verbal connexions which we were able to ascertain from our subjects was, as a rule, also of a selective nature. But the nature of this selectiveness was different and less clearly manifest than in normal persons, and the more profound disturbance of the mental activity and the corresponding disturbance of the intellectual process, the greater was the disturbance of the system of links elicited in these cases.

In children having a relatively less manifest form of oligophrenia (oligophrenia in the debility stage—and mainly the older age-group, 15–17 years old) we could, as a rule, observe a peculiar fact: the system of dominant connexions comprised *both words near to the key word in meaning and words similar to it in sound*. Vascular orienting reactions were evoked here, both by the word 'sobaka' (dog) which is linked in meaning with the key signal word, and by the words 'kroshka' (crumb) and 'okoshko' (window) which have

* As regards oligophrenics, we took only those children having undergone, either while still in the womb or during early development, a severe cerebral lesion as a result of which they showed mental defect.

merely a superficial phonetic resemblance to it. However, a motor reaction resulting from verbal instruction was evoked only in response to the signal word, 'koshka'. This fact has the characteristic feature that, if vascular reaction to the latter words (similar in sound) occurred after a short latent period, being thus immediate in character, then the vascular reaction to words having a sense-link with the key word occurred after a significant latent period (up to 7 or 8 sec.), and hence arose as a result of another considerably less direct process. This fact illustrated in Fig. 2 gives grounds for important conclusions with regard to both the smaller selectiveness of the system of word links in the mentally retarded children and to the different actualization of sound and meaning systems which are characteristic of a pathologically altered cerebral activity.

We are able to observe even more significant changes in the system of connexions, in experiments with children, having the defect in a more serious degree—or with debile children of the younger age-group (12–14 years).

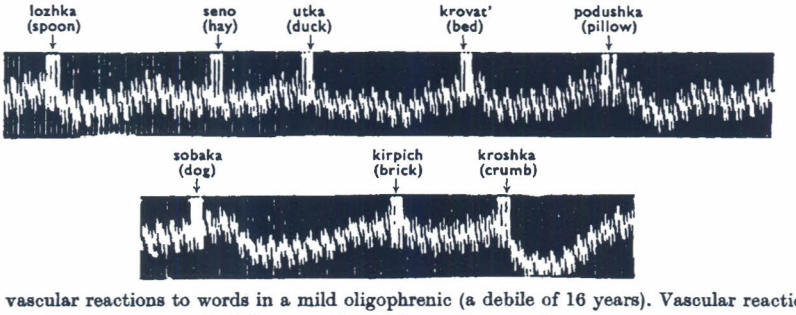

Fig. 2. The vascular reactions to words in a mild oligophrenic (a debile of 16 years). Vascular reactions occur both in semantic and in sound connexions.

As a rule, words close to the key word in meaning, 'kryssa' (rat), 'sobaka' (dog), 'zhivotnoye' (animal), did not provoke orienting vascular reactions and consequently did not generally come into the sense-system, worked out by us (only those words having a direct connexion to the key word proved the exception; such as, for example, the word 'kotyonok' (kitten). Instead, words having a sound similarity to the critical word (e.g. 'kroshka' (crumb), 'kryshka' (lid), 'kruzhka' (mug), 'okoshko' (window), etc.) continued to evoke a vascular reaction; i.e. the nature of the links discovered was directly opposite to that observed in the norm. It is interesting that the word 'myshka' (little mouse) also evoked the active tentative vascular reaction; but when only the root of this word was left ('mysh' = mouse) and the sound resemblance ('--shka') to the key word eliminated—it ceased to evoke the vascular reaction.

In even more serious forms of oligophrenia (imbecility) the specificity of the responsive motor reaction disappears. Despite precise instructions to press the button only in answer to the word ('koshka') the subjects reacted in this way to words similar in sound to the key word. In this way pathological deformation of the verbal system is associated with disturbances of the voluntary motor reaction, which reveals the same defects as the involuntary vascular component of the orienting reaction. But even in these cases the motor reaction remains less diffuse in character than the vascular. Thus if a vascular reaction is evoked even by words so dissimilar to the key signal, such as 'chashka' (cup) or 'kruzhka' (mug), then the motor reaction occurs only with those words most similar in sound (e.g. 'kroshka', 'okoshko').

All these facts, an illustration of which is given in Fig. 3, clearly indicate that *the system of links resulting from a word is distinctly altered and pathological in character, and that the dominant position of selective semantic connexions disappears here*, while *sound*-resemblance, not of a selective sense-link nature, begins to occupy the leading position. It is characteristic that this disturbance of the semantic system is evident here too, and the system ceases to be clearly divided into the group of *central signals*, provoking a motor reaction, and the group of *peripheral verbal signals* which do not provoke a motor reaction, but which only result in the evocation of distinct vascular reactions.

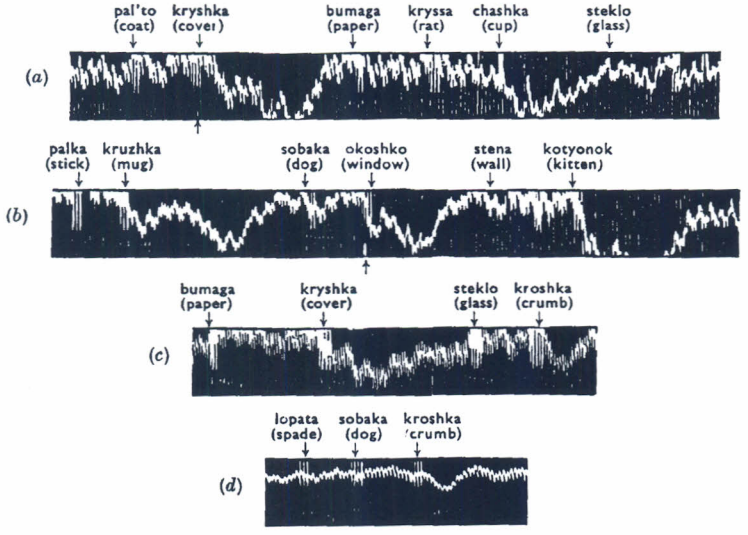

Fig. 3. (*a*) The reaction to words of an imbecile (16 years). Not only vascular reactions but also arbitrary motor reactions are disturbed. Explanation given in the text. (The motor reaction is registered by a vertical line ↑ in the lower part of the tracing.) (*b*) and (*c*) are examples of vascular reactions in child oligophrenics (debiles of 12–14 years). While there is an absence of reaction to words having semantic connexions with the signal word, reactions to words similar in sound to the signal are observed.

4

An objective analysis of the semantic system is not limited to the study of the structure which we have just described. It permits us to go on to the analysis of the *dynamics* of these connexions and the changes in them which depend on the state of the subject and the conditions of the experiment.

In the dynamics of the experiments carried out on our subjects, who revealed the described pathological change in the system of meaning connexions, we are able to record two factors which act in a mutually opposing direction. One of these is the factor of *training* or *exercise*, which intensifies the selective nature of the connexions; the other is the factor of *fatigue* or *exhaustion*, which leads to an inhibitory state of the cortex and disturbs the system of selective connexions.

Among our subjects were a number of slight oligophrenics, who in the original experiments revealed characteristic pathological alterations in the system of verbal connexions. There was an absence of vascular reaction to stimuli similar in meaning, in the

presence of vascular reactions to words similar in sound. But in the course of the experiments, with repeated reinforcement of the signal word, 'koshka', there was a material change in the situation. The subject began to form a system of selective semantic connexions, evident in that words having an outward sound resemblance to the key word ceased to evoke a vascular reaction, while words linked in meaning with the key word acquired a signalling character. An example of such an effect of training is shown in Fig. 4.

Fatigue, effecting an inhibitory state of the cortex acted in the opposite direction. This could be discovered by carrying out experiments twice in the course of a day—morning and evening. Thus in the experiment with an oligophrenic of the older age-group (18 years old) carried out in the morning before he began his school work, normal relations

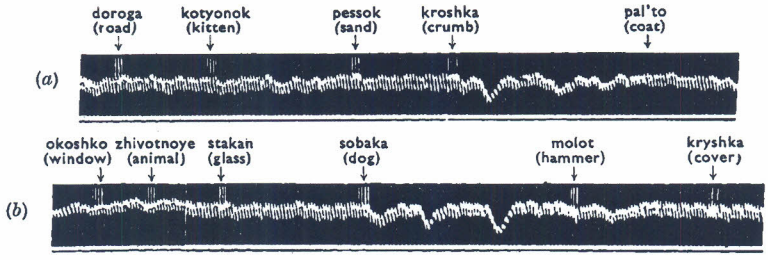

Fig. 4. The effect of training on the dynamics of semantic system in an oligophrenic (a debile of 12 years). Sound-similarity gives place to adequate semantic connexions. (*a*) First experiment; (*b*) fourth experiment.

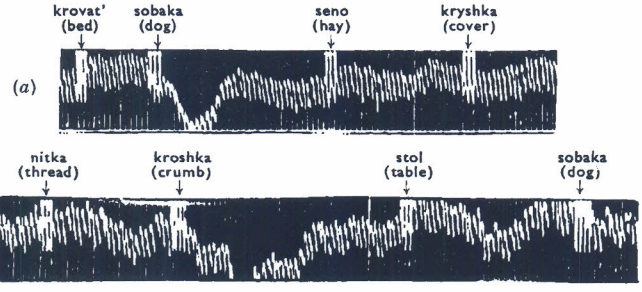

Fig. 5. Effect of fatigue on the semantic system of an oligophrenic (a 17-year-old debile). Adequate semantic system gives way to primitive sound connexions. (*a*) Before lessons; (*b*) after lessons.

in his word system were ascertained. Then an experiment of the same sort was repeated after 6 hr. of work in class. In this experiment were revealed a disintegration of sense-links and the occurrence of reactions to words resembling the key word in sound; i.e. a more primitive system of connexions (Fig. 5) was shown. The same phenomenon was observed in the presence of headaches, influenza, and other disturbances of the general condition of the subject.

The dynamics of semantic systems discovered in our experiment is not defined by the factors of the general condition of the subject alone; they may depend on a *number of inner conditions of experiment*, on the basis of which we may have the possibility of *controlling the dynamics of the systems investigated*. The *inclusion of the word in a definite context* can serve as one of the clearest examples of such a control. We have already said

that a fact, characteristic of deeply affected oligophrenics, is the appearance of primitive verbal connexions owing to an outward sound resemblance as a result of which the word 'okoshko' (window) having merely an outward sound resemblance to the signal word, 'koshka' (cat), begins to evoke vascular reactions. But if, by the introduction of this word into a definite, specially selected series of words, we intensify its own semantic connexions, the sound resemblance to the signal word can be inhibited and this word stops evoking vascular reactions. We give an example of such control of the sense-links in Fig. 6. Without interrupting the experiment with the oligophrenic subject in whom the word 'okoshko' provoked a tentative reaction by virtue of its resemblance in sound to the word 'koshka', we introduce this word into a context of words relating to other parts of the house—giving consecutively the words 'dom' (house), 'dver' (door), 'stena' (wall), 'okoshko' (window). Under such circumstances, the proper semantic field of this word is intensified, its sound resemblance to the signal word loses its significance, and the same word now ceases to evoke an orienting reaction linked with the signal word.

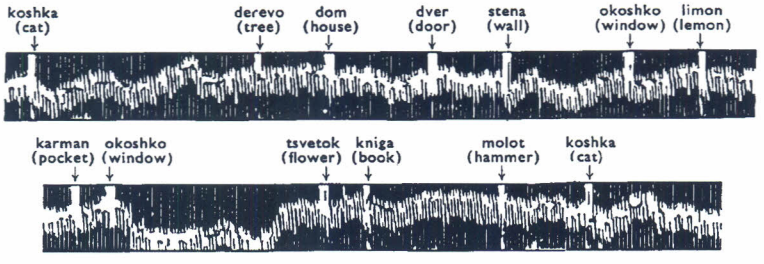

Fig. 6. The influence of 'context' on the effect of a word stimulus in a child oligophrenic (a 13-year-old debile). The introduction of words into the corresponding semantic system brakes the effect of its sound similarity with the signal word (explanation in the text).

The given experiment, being an attempt at active influence on the structure of the word-system which has been revealed, and at controlling the dynamics of this system, may suggest new lines for the investigation of different aspects of the conscious organization of sense-activity in the normal as in abnormal subjects.

5

So far we have only considered the general indicators of the presence of semantic systems which we were enabled to approach through the method of recording of the vascular components of orienting reactions.

Can we not, however, take a further step and try to introduce a further qualitative analysis into the structure and dynamics of those potential links which we have just described?

For this purpose we must modify the method and use such means as would allow us to *differentiate variants* of such potential sense-links, not only in quantitative terms (more or less intensive reaction) but when possible in *qualitative* terms also. The method which one of us (Vinogradova, in collaboration with Heissler*) had used was found suitable for these problems too.

In the variant of the method used for these purposes, we discarded the motor reaction

* A report of this work is in preparation.

of the subject, but replaced orienting reinforcement (conditioned by giving special significance to one of the verbal stimuli) with a *pain* reinforcement. The given method is based on data obtained earlier in our laboratory by Vinogradova & Sokolov (1957). As these experiments showed, thermic stimuli, which provoke specifical thermoregulatory vascular reactions, and also pain stimuli evoked characteristic changes in the blood vessels of the hand and of the surface of the head. These changes are expressed in the parallel contraction of the blood-vessels of the head and of the hand under the action of pain and cold and in the dilatation of the said blood-vessels under the action of warmth. However, these specific reactions do not arise at once, and in the first experiments they are preceded by non-specific (alike in all cases) *orienting* reactions consisting of the *dilatation of the blood-vessels of the head and the contraction of the blood-vessels of the finger*. Only thereafter does this non-specific reaction fade out and change into the specific (adaptational or defensive) reaction mentioned above, during which the reaction bears the same character both in the blood-vessels of the head and in the blood-vessels of the hand (see Fig. 7).

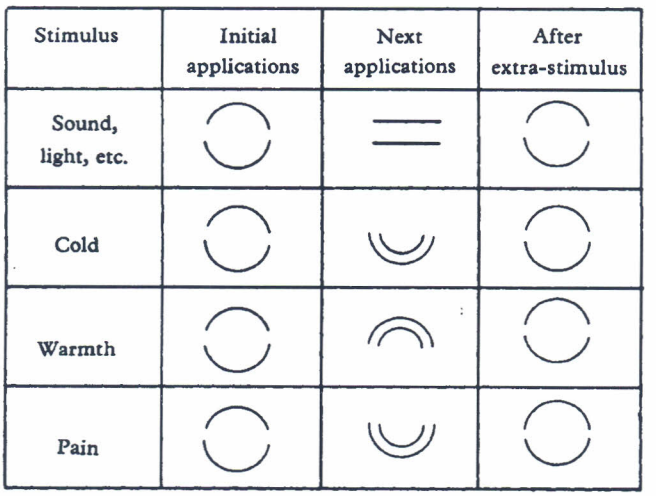

Fig. 7. The scheme of the relation of non-specific orienting and special reactions to different stimuli during recording of the plethysmogram of the blood-vessels of the finger and the surface of the head.

This basic fact was used by us for the further objective differentiation of the dynamics of semantic system. This series of experiments was carried out on seven normal adult subjects. When the preliminary orienting vascular reactions had faded out on all words, we began to accompany one of them (in this series of experiments it was the word 'skripka' (violin)) with a painful electric stimulation applied to the skin—a current of 45 volts. In accordance with our earlier data the reinforcement of the word 'skripka' (violin) with a current at first evoked a reaction of an orienting nature (contraction of the finger blood-vessels and dilatation of the blood-vessels of the head) which was gradually replaced by the specific pain reaction (parallel contraction of blood-vessels of the head and hands) only after 18–25 repetitions of such combinations.

At this phase we went over to the basic tests. Among various 'neutral' words we

began to introduce words having semantic connexions with the basic stimulus ('skripka') or having a sound similarity with it.

It became clear that the words we used provoked reactions of varied character. A fairly wide group of words, in spite of the fact that they had not been reinforced by current, *evoked exactly the same reaction as the basic stimulus, that is the specific pain reaction of parallel contraction of the blood-vessels of the hand and the head.* As the analysis shows, this group of words obviously had a more direct close link with the key word 'skripka' (violin). It included such words as 'skripach' (violinist), 'smychok' (bow), 'struna' (string), 'mandolina' (mandoline), 'kontrabas' (double-bass) and several other names of stringed instruments. Besides this group of words there was another still wider group which also evoked vascular reactions, *although these reactions were not defensive but orienting in character, that is were expressed in the dilatation of the blood-vessels of the surface of the head and the contraction of the finger blood-vessels.* To this group belonged: (*a*) names of stringless musical instruments ('akkordeon' (accordion), 'klarnet' (clarinet), 'baraban' (drum), etc.); (*b*) other words connected with music ('sonata', 'kontsert' (concert), etc.); (*c*) in a number of cases the same reaction was evoked by words close to the key-word in sound ('skrepka' (paper-clip)). In addition to this, 'neutral' words did not evoke any changes in the vascular curve (e.g. 'shkaf' (cupboard), 'sapog' (boot), 'oblako' (cloud), etc.).

In the further conduction of the experiments, this phase of *primary systemic generalization* changed over into a phase of *concentration*: only the key word ('skripka') reinforced by the current continued to provoke a distinct specific (pain) reaction. *All* words close to it in meaning began to evoke an orienting vascular reaction. The group of words, which in previous experiments had evoked an orienting reaction (including also words without a semantic connexion with the key word, although similar in sound to it) ceased to evoke any vascular reaction whatsoever and became completely neutral. Finally, in further experiments came the stage of *full concentration*—only the key word as before kept its defensive action; all the remaining words, including even the closest in meaning, went over to the category of neutral words. An example of such dynamics of vascular reactions to various words is given in Fig. 8.

It is characteristic that the facts described above, i.e. the dependence of the objective vascular reactions to a given word on its context and the possibility of directing the signal meaning of words, are repeated in a new form here also. The word 'truba' (pipe or chimney) which had given a distinct orienting reaction, when said out of context, ceases to give it if the word is included in the context 'dom' (house) 'pechka' (stove), 'krysha' (roof), taking on by that very fact the meaning 'chimney' (Fig. 9).

All these facts allow us to come to two conclusions.

The objective study of vascular reactions under the conditions of our experiments allowed us to affirm the fact that all the words are divided into three groups: (1) *the nucleus of the semantic complex*, to which is related the key word and words in direct semantic proximity to it (they evoke a specific pain reaction); (2) *the periphery of the semantic system* to which are related words linked less directly with the key word (evoking a non-specific orienting reaction); and (3) *neutral words*, which in our experiment did not evoke any specific or orienting reactions.

The correlation of these groups at various stages of the experiments may be different, and if at the beginning of the experiment the nucleus of the semantic system has a

relatively generalized character, then later it becomes concentrated and only the key word continues to provoke a specific reaction, while the remaining words, which earlier were included in this nucleus, move into the semantic periphery and begin to evoke only a non-specific orienting reaction.

In the method used we gain consequently the possibility of taking one more step along the path towards the definition of the *structure and dynamics of semantic system*, to the objective study of which we have dedicated our research.

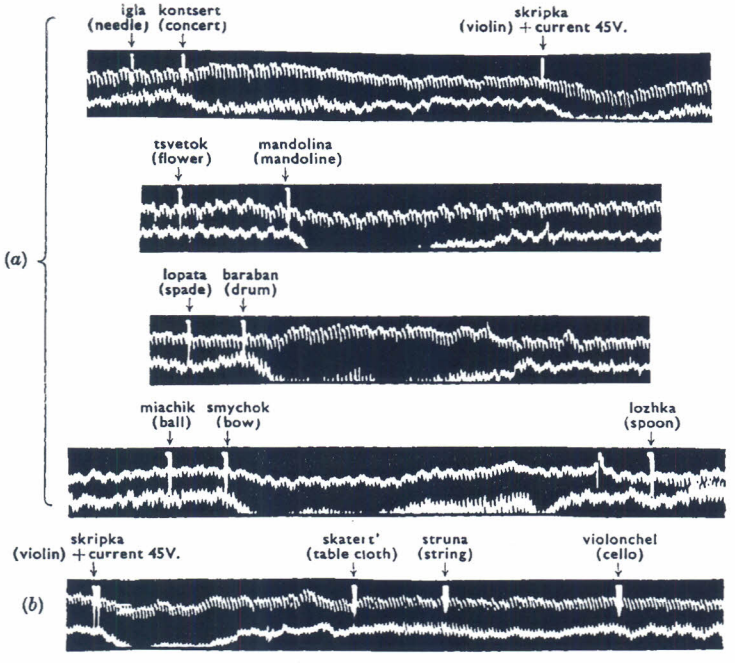

Fig. 8. (*a*) The initial differentiation of word stimuli during the working out of the conditioned defensive reflex to the word 'skripka'. The words 'smychok' (bow), 'mandolina' (mandoline), evoke a defensive reaction; the words 'kontsert' (concert), 'baraban' (drum)—a reaction of the orienting type. (*b*) The stage of final concentration (fifth experiment)—only reaction to the reinforced word remains. In each record the upper plethysmogram is that of the blood-vessels of the surface of the head, the lower plethysmogram is that of the finger blood-vessels. The double horizontal line register sthe unconditioned reinforcement by electric shock.

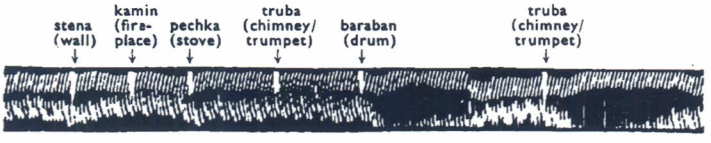

Fig. 9. The influence of a semantic text on the appearance of different connexions of one and the same word, from the phonetic point of view (homonyms). Explanation in the text.

6

We have traced the natural dynamics of semantic systems obtained by us in those conditions where we reinforced only one key word. We saw that by the repetition of the experiments in accordance with a definite plan, we reach a certain stage when the extended

connexions of the given word ceased to appear, since the limit of concentration of the system has been reached. However, at any moment we can restore the whole semantic system being investigated, in all the fullness of its connexions. For this it is sufficient to reinforce with the current one or two words, besides the key word 'skripka', *relating to the same system* ('mandolina', 'gitara' (guitar), etc.). A single reinforcement of these words with the current leads to the immediate *restoration of the whole active system of words*, linked by direct and indirect connexions with the basic stimulus. When this is done there appears again the field of words closer to the basic core, which evoke defensive reactions, a semantic periphery, evoking only orienting reactions and a neutral zone which does not change its indifferent character as regards vascular reactions. Fig. 10 gives an example of such a change.

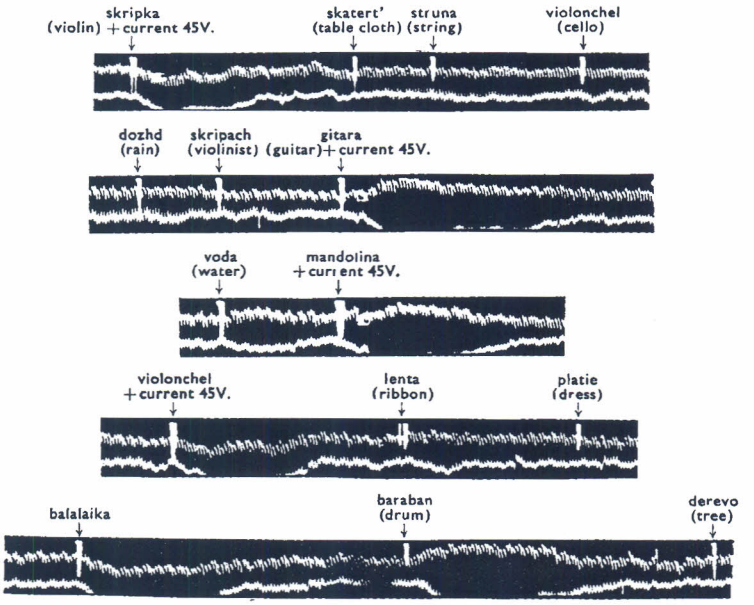

Fig. 10. The effect of the reinforcement of new words of a semantic system ('gitara', 'mandolina', 'violonchel') on the participation of a reaction. The initial differentiated effect of word stimuli is restored.

The systemic nature of the restoration of differentiated vascular reactions becomes even more obvious if, in the capacity of a control, we introduce the following experiment. At the stage when only the basic word 'skripka' (violin) preserves its action, *we reinforce with the current another word, having no relationship with the system investigated earlier, for example the word 'korova' (cow)*. Such a method does not have a restorative influence on the earlier system (the 'skripka' system)—its components remain indifferent as regards vascular reaction. The new reinforced stimulus creates *its own system* in which, as we already know, the character of the reactions is differentiated according to the degree of proximity to the basic irritant (such as the words 'byk' (bull), 'telyonok' (calf), etc., evoke here a defensive reaction, the words 'stado' (herd), 'moloko' (milk), 'sobaka' (dog) evoke an orienting reaction, and so on). Thus these two systems, foreign to each other as regards their semantic fields, turn out to be, as it were, absolutely isolated in their

objective manifestations. However, this is not entirely correct, and with the help of a special variation of our technique we can discover the mutual influence of the two semantic groups created by us.

If we begin to reinforce the word 'korova' (cow) before the final differentiation of the 'skripka' system, that is when the elements nearest it continue to evoke orienting reactions, we will see that the mutual influence of the two systems does, in fact, take place. If after several reinforcements of the word 'korova' we use the words of the previous system, which had just evoked distinct orienting reactions, they turn out to be inactive.

Thus, the rise of a new dominant semantic system sharply differing from the system which had existed earlier leads to a *temporary inhibition of that system*, to the breaking of its own peripheral links, though the core (defensive reaction to the word 'skripka') is relatively well preserved.

Alternating periods of the reinforcement of the word 'korova' with periods of reinforce-

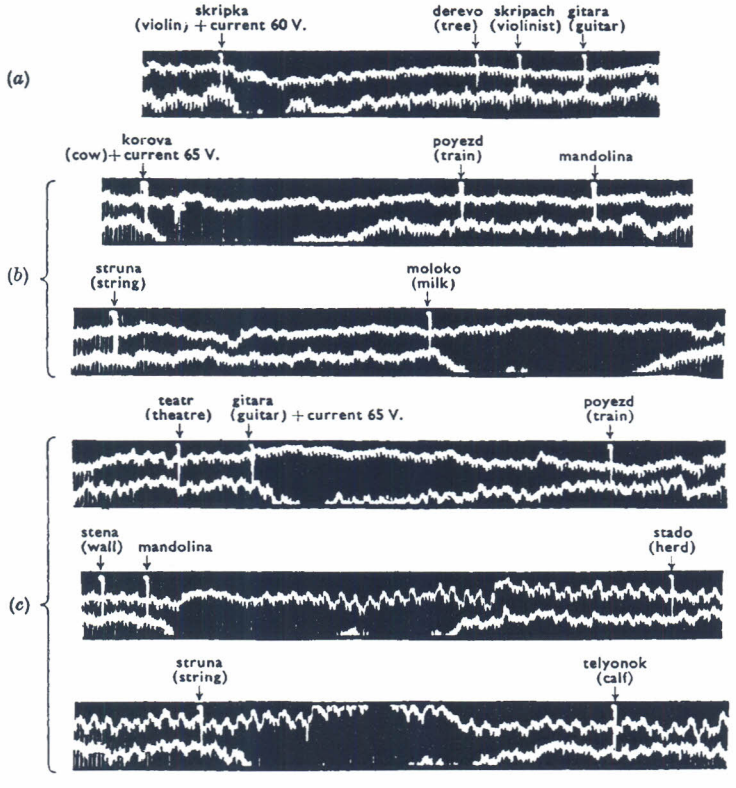

Fig. 11. The conflicting effect of the reinforcement of another semantic system ('korova'—cow). With the appearance of a new group of signal stimuli ('moloko'—milk, 'telyonok'—calf) the action of the stimuli of the initial sense system ('skripka', 'gitara', 'mandolina', 'struna'—string) is braked. A new reinforcement of the initial semantic system (gitara + the electric shock) leads to the suppression of reactions to the words of the new complex ('stado'—flock, herd, 'telyonok'—calf) and the renewal of the former complex of links (mandolina, struna). Simultaneously, a conflicting state arises manifesting itself in the change in character of the vascular curve. (*a*) Reinforcement of the word 'violin'. (*b*) Reinforcement of the word 'cow' (twice). (*c*) Reinforcement of the word 'guitar'.

ment of the word 'skripka', we can repeatedly change the nature of the action of the test words, which relate to the one and to the other system. The activation of the system of the word 'skripka' (by means of using this word, reinforced by the current, two or three times in succession) leads to the suppression of the links of the 'korova' system, and vice versa.

The given semantic systems turn out to be mutually exclusive, the actualization of one sense complex leads to the repression of the other.

This work on the repeated reconstruction of the system of sense-links does not pass by without leaving its mark on the subject. Respiratory waves, appearing on the plethysmographic curve, general volume oscillations and irregularity of the pulse point to the difficulty with which this reconstruction arises and to that irradiated disorganization of the vegetative processes, which is a symptom of the difficulties which occur. Fig. 11 gives an example illustrating this state.

Experiments with the reversal of semantic fields and with the study of the objective symptoms of this reversal open up important perspectives of research. They permit the objective approach to the dynamics of the conflict of two systems, of the 'suppression' of a system, which results from such a conflict and of that general reaction to the switching of dominant systems, which were studied by Pavlov in animals, and in the early works of one of us (Luria, 1932) were just tentatively traced in man.

7

We have examined the facts which were obtained with the help of the objective method of studying vascular reactions to the appearance of a signal word.

We have still to discuss a final, but very important, question—what is the relationship of the semantic system appearing in the objective symptoms described above, to the system of conscious connexion which may figure in the *verbal account of the subject*? The fact that in the first series described above vascular reactions also accompanied those signals which by themselves did not evoke motor reactions compels us to think that *by no means all the links reflected in them occur equally consciously*, and that in many cases *vascular reactions reveal potential systems of links more fully than the conscious account of the subject is able to.*

In order to verify this basic question we interrogated our subjects at the termination of the described series of experiments.

The results obtained from such an interrogation were sufficiently uniform. The subjects, as a rule, *were unable either exactly to formulate the aims of the experiment, or to designate exactly that group of words evoking definite vascular reactions.* An extract from the report of the interrogation of one of the subjects may serve as an illustration of this position.

Subject A. S. (scientific worker, 25 years old). Experiment no. 4, 4 May 1957
Tell us what happened during the experiment?

All kinds of words were said, without any system, in my opinion. No, in general, you probably have a system, but I do not know it—the words were very different. After certain words, the shock was given. These words were 'gitara' and 'skripka'.

What other words do you recall?

'Doroga' (road), 'korova' (cow), 'lozhka' (spoon), 'salat' (lettuce), 'mandolina' (mandoline), 'akkordeon' (accordion), 'kosa' (scythe); 'koryto' (trough)—that was the first word.

What did you feel, what was your attitude to the experiment?

I took it as a matter of course, and did not react to anything. When there was a shock after new words I was surprised, but not much.

Can you not say what was the aim of this work, was there no special choice of words, or links between them?

I don't know....I don't even imagine....You see the words were so varied....

Perhaps some words occurred more often than others?

I did not pay any attention to that. In my opinion the word 'lozhka' (spoon) was somehow repeated. Well, 'skripka' was repeated, of course, and 'gitara'.

Can you not apply a single word to a section of the words used?

Well, I don't know....I believe they were musical words, the names of musical instruments, but in general they were very varied.

You are right. You were given names of musical instruments. But why were you given these particular words?

Probably...of course, you gave me a shock after the word 'skripka'...I can guess...oh, and after 'gitara' too!

Has it occurred to you, or did you guess it during the experiment?

No, I didn't think of it then; for me there was no connexion of words.

Thus the system of links revealed by us, is not of a clear conscious nature, and *it is reflected much more fully in the system of vascular reactions than in the conscious account of the subject.*

The semantic analysis of connexions formed in the subjects is confirmation of this peculiarity. It shows that the semantic system which is formed can only with difficulty be fitted into any strict logical system of concepts. Thus, for example, the group of named musical instruments, which evoked, in the first stages of the experiments the same defensive reaction as the word 'skripka' could be joined in one logical category as 'stringed instruments'. But, together with this, the word 'arfa' (harp), for example, never evoked a reaction of a similar sort, which compels us to suppose that the principle of the similarity of a certain situation or the outward shape of the instrument also played a substantial part in the process of the revelation of the semantic field under investigation. Hence it is evident that it would be a great mistake to approach the real semantic field arising in the brain cortex of the subject as a system of logical categories, which is sometimes of a broader, sometimes of a narrower character.

The absence of adequate identification of the semantic field obtained in these experiments revealed objectively in the experiment agrees completely with the analogous data of Lacey & Smith (1954), who had used as indicators of verbal connexions which occurred changes in the pulse rate and the skin-galvanic reflex. In their experiments also, the subjects did not reflect in their report connexions which it was possible to ascertain by means of objective indicators. Another point of view is held by Razran (1949*b*), who considers that the generalization of stimuli occurs as a result of the evaluation of a new stimulus on the principle of similarity-difference, and can be revealed as a result of introspection. However, he himself shows (1949*a*) that the introduction of various