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From Fundamental Principles of Memory Organization Towards Neurorehabilitation: A Literature Review and Case Report

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Background. Contemporary rehabilitation of memory impairments relies on the use of external compensatory strategies. In Russian neuropsychological tradition, rehabilitation is understood as a transformation of a higher mental function, based on intact elements of that function and on use of external and internal means. Such a restructuration approach may be applied to memory.

Objective. This article describes the basic principles underlying memory rehabilitation and gives an example of their successful implementation in a clinical case.

Design. A 62-year-old patient was admitted 6 months after severe traumatic brain injury with primary damage to his left frontal and temporal lobes. He faced difficulties in social living and activities of daily life, mainly due to memory impairment. Neuropsychological assessment revealed moderate impairment of different memory types: modal nonspecific impairment with mild but persistent impairments in autobiographic and semantic memories. During a 3-week rehabilitation program, an algorithm involving the use of text was developed in consideration of the structure of memory impairment (impaired selectiveness, excessive inhibition and pathologic inertness of memory traces).

Results. After multiple trials and modifications, the resulting algorithm (written retelling with the use of keywords, self-correction with writing correct variants instead of errors), allowed reproduction of the presented text with 100% recall of significant information and no false memories. The use of the developed memorization technique in everyday life allowed the patient to effectively memorize relevant information.

Conclusion. The described approach—restructuration of memory on the basis of preserved chains—is a feasible strategy of memory rehabilitation.

Keywords: neuropsychological rehabilitation, neurorehabilitation, memory, traumatic brain injury

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Introduction

Due to the low potential for restoration of memory after brain injury, contemporary rehabilitation of higher cortical function mostly involves external compensation (Dubourg, Silva, Fitamen, Moulin, & Souchay, 2016; Evald, 2017; Jamieson, Cullen, McGee-Lennon, Brewster, & Evans, 2014; Wilson, Gracey, & Evans, 2009). According to multiple studies, memory training has poor efficacy (das Nair, Cogger, Worthington, & Lincoln, 2016; Hamalainen & Rosti-Otajarvi, 2016). Russian neuropsychological tradition, which is based on the work of L.S. Vygotsky and A.R. Luria, offers another approach to rehabilitation of memory impairments — restructuration of impaired higher cortical function on the basis of preserved chains with the use of internal and external aids. This includes either the reconstruction of an existing functional system or the formation of a new one, relevant both to the patient's individual needs and to his/her brain abilities.

L.S. Vygotsky believed that memory is a higher mental function which, better than other functions, reveals the individual's interaction with him/herself. A productive and efficient interaction with him/herself in everyday goal fulfilment is probably a key objective of neuropsychological rehabilitation.

In Russian neuropsychological tradition, based on L.S. Vygotsky and A.R. Luria's works, rehabilitation (or impaired functions' recovery) is understood as a transformation of a higher mental function, based on intact elements of that function and on use of external and internal means (of mediation) (Luria, 1976; Vygotsky, 1997). Often that process is based not only on rehabilitation of a partly or completely damaged function, but also on a modification of how that function is realized. Concerning memory, it is "working with memory" or developing a new way of an individual's interaction with himself/herself, rather than just "memory rehabilitation".

Principles of Memory Organization

The transformation of primitive (biological) forms of memory to higher (specific for humans) forms is a result of a long and complex process of cultural and historical development. Memory of modern humans, as a higher mental function, is also a product of their cultural and social development (Leont′ev, 1964; Vygotsky, 1997). That is why means and mechanisms of memorization (used by an individual during his/her lifespan) act as products of interaction of a person with him/herself through the development process. In the case of abnormalities, especially related to brain injuries, many of these well-developed and established means of interaction became inefficient. As a result, there is a need to "repair" such means or to search for new means which, on one hand, will correspond to the capacities, individual characteristics and patient's requests, and on the other hand, correspond to the abilities of his/her damaged brain functions.

The above-described principles are related to the theory of metacognitive functions developed in modern psychology (Ackerman & Thompson, 2017; Al Banna, Abdulla Redha, Abdulla, Nair, & Donnellan, 2015). The development of metacognitive functions begins in the earliest periods of ontogenesis and continues until the later youth period and, in some cases, continues during the whole lifespan. Usually two elements of metacognitive functions are damaged in the case of brain

injuries: difficulties of awareness of the existing deficit (which includes poor self-monitoring) and absence of the flexibility and behavior change which is important when external conditions are changed (Kennedy & Turkstra, 2006). As a result, these patients need special training of metacognitive functions (Kovyazina et al., 2017; Varako, Dobrushina, Zinchenko, Martynov, & Kovyazina, 2016).

Most often, training of metacognitive functions is used in rehabilitation in three cognitive domains: attention, executive functions and memory. The authors divide all metacognitive strategies into two categories (Sohlberg & Turkstra, 2011): task-specific strategies (for example, for understanding and remembering the information) and general strategies (for a wider range of tasks).

Mechanisms of Memory Impairment

The excitation-inhibition processes of balance (neurodynamic balance) and an optimal energy level (remaining active long enough to memorize and retrieve information) are important conditions of memory processes. If the level of optimal energy is low, neurodynamic balance is disturbed: the inhibitory processes predominate as an abnormally increased retroactive inhibition. As a result, if after the act of memorization some new action appears, the subject has difficulty retrieving recently memorized information (forgetting). This action causes an inhibitory (interfering) effect on retrieval efficiency. Thus, ***increased inhibition*** of memory traces due to the impact of interference is one of the main mechanisms of abnormal forgetting (Luria, 1976).

It is important to note that increased inhibition of memory traces due to the impact of interference can, in one case, appear in all modalities (in memorization of visual, motor and auditory stimuli), while in other cases it may appear only in one modality. Moreover, the intensity of polymodal and unimodal memory impairments, diagnosed during clinical and neuropsychological assessment, depends on interference type (inter- or intra-stimuli interference), level of semantic organization of stimuli and combination of numerous conditions of memory task (Korsakova & Moskovichute, 2003).

If we consider that memory retrieval presumes guidance towards a memory trace relevant to the task, it is clear that an ability to control the selective memorization is another condition of memorization's efficiency. In the case of damage of cerebral structures, the selective memorization of memory traces relevant to the task is troubled; together with the stimuli relevant to the task, some irrelevant stimuli are also memorized in an involuntary and automatic manner. Thus, ***difficulties of selectivity of memory traces*** (related to present and past experience) can be another mechanism of memory impairment.

Optimal *flexibility* of neural processes, which allows one to switch from one element (or association) of memory trace to another, is one of the neurodynamic parameters of mental activity. In the case of flexibility impairment, the ***abnormal inertia*** (which manifests itself in perseverative retrieval of some elements of memorization task and details of past experience, as well as in proactive inhibition, when the action which appeared before the memorization act has a negative impact on the result) might be a mechanism of memory impairment.

Human memory is, first of all, an active memorization activity. It means the individual transforms the information he/she perceives in an active manner, not

just imprinting the traces of stimuli, but encoding the information, selecting its relevant and irrelevant characteristics and encoding the stimuli in a specific system — a semantic and subjective organization (Leont′ev, 1964; Luria, 1976). Moreover, the active manner of information transformation manifests itself when a person addresses a special task to remember information in a particular condition or situation. Such an activity, directed towards a goal, induces a selective character of the memorization process (the use of specific means and development of relevant motivations and attitudes), as well as the retrieval process (the access of relevant information at a proper time).

Principles of Rehabilitation of Memory Impairments

In the Russian neuropsychological approach, based on L.S. Vygotsky's ideas, the higher mental functions have specific characteristics or processes which enable learning something new, as well as recovery after impairments during neurorehabilitation (Vygotsky, 1997): *exteriorization* and *interiorization.* What do these terms mean? The studies of higher mental functions among children revealed that any complex mental activity is *exteriorized* in the beginning (carried and expended on the outside). For example, when children learn to solve arithmetic problems, they rely on external means — means which are well known and understood by the child (for example, arithmetic tasks using apples). Gradually, these external means are replaced by more abstract algorithms, such as rules how to solve arithmetic tasks, which are exteriorized as notes, schemas, etc. Eventually a child does not even use these exteriorized means. It happens because logical operations become automatic and are transform into "mental skills". Thus, *interiorization* of some particular logical operation develops, being transformed from an external to internal form (Furth, 1968).

A similar process develops during phylogenesis: the transformation of primitive, biological forms of memory to higher, specifically human, forms of memory. This is a result of a long and complex process of cultural and historical development: being exteriorized and based on external means in the beginning, gradually memory becomes the one we can now observe in modern humans.

The first steps towards intentional memory regulation appear among primitive tribes. These are the first attempts to regulate one's memories, to retrieve memory traces by means of a special stimulus which act as *means of memorization*. Janet said: "The first memories are the memories of things by means of the things themselves. A person who wants to retrieve a memory takes a special object in hand; for example, some tie a string on a foulard or put a small stone in a pocket, a piece of a paper or a leaf from a tree. This is what we still call *souvenirs*" (Janet, 1928). Mechanically retained memory traces need to have an essential connection with a stimulus existing in a novel situation to reappear in mind in that novel situation. This mediating element, which connects the trace of memory with a novel situation, must be created beforehand in the memorization process.

It is important that the studies of compensation mechanisms (in the case of some functional system impairment) revealed that there are no principal differences between the reorganization of the function in abnormal and normal conditions (Anohin, 1958). That means that reorganization mechanisms are universal.

Thus, the principal objective of the rehabilitation process is to look for individually intact abilities, which can maintain the development of that universal mechanism.

After brain injury, key elements of the comprehensive interiorized memory system can be destroyed. During neuropsychological assessment, impaired and preserved chains of the system are identified along with resources which may be used to create a new system. Subsequent rehabilitation is a highly exteriorized elemental process, aimed to find an effective strategy to work with memory. Once such a technique is found, it is trained to promote consolidation.

Design

Case Report Description

Patient L., 62 years old, had a severe traumatic brain injury along with thoracic trauma (fracture of the right III-VII ribs and left IV rib, pulmonary contusion, secondary pneumonia) and traumatic shock as a result of an automobile accident which happened 6 months before rehabilitation. Brain CT and MRI revealed multiple abnormalities, including sites of traumatic injury in the left anterior-lateral frontal area (2 cm^3) and left temporal area (2 cm^3), multiple "vascular" lesions in the white matter of the frontal and temporal lobes and moderate hydrocephalus. During the first month after the trauma, the patient had disordered consciousness, starting from stupor (GCS 11), with gradual restoration. He received intravenous fluid therapy, antibacterial therapy and sedation with benzodiazepines due to delirium. One month after the trauma, he was discharged.

The patient has an engineering degree. Before the injury, he worked as an electrician and helped his son in apartment renovation work. Because of memory difficulties after the traumatic brain injury, the patient left his job and stopped participating in his family life. He could not internalize the contents of books and web pages he read. In his daily routines, the patient often forgot where he put objects and what he planned to do.

Six months after the trauma, the patient was admitted for rehabilitation. The diagnostics of higher mental functions (e.g., memory) was based on classic neuropsychological assessment in A.R. Luria's approach. The results of neuropsychological assessment are presented below.

Neuropsychological Assessment

During assessment, the patient was communicative, sociable and emotionally adequate. The anxiety which appeared in the beginning of the assessment was transformed into a calm mood. The patient made jokes, showed his interest in task performance and was an active participant in the discussion. He was not particularly aware of errors he made during the assessment.

Objective Results

Difficulties in kinetic praxis were revealed. These difficulties were manifest in difficulties of motor stereotype development, organization of series of movements, propulsions, perseverations and dominance on the left side. Also, there was a tremor in both hands (but mostly in the left hand).

The second complex of symptoms includes different memory impairments. Firstly, impairments of elements of neurodynamic conditions of memorization: impairment of selectivity of memory traces of past experiences (the patient had contaminations and confabulations), increased inhibition of memory traces due to the impact of interference (also appeared in semantic information memorization), abnormal inertia of memory traces (appeared in inert memorization of relevant and, at the same time, irrelevant answers in memory tasks). Secondly, there were memory impairments of different severity levels which appeared in retrieval of memories from past experience and autobiographic memory:

- The productivity of correct memorization and retrieval of short stories was approximately 90%; the quantity of errors of "false memorizations" was 4-5, gaps in significant details — 4-5. Indirect (unmediated) memorization-delayed retrieval was less than 30% of the whole text amount with loss of its meaning; in mediated memorization, 70% without any loss of its meaning; however, a loss of significant details occurred.
- There was low efficacy in a memorization task (remembering a series of words). During five attempts to remember a series of words, the increase of memorized and retrieved words was two words and reached a maximum of only eight words.
- The increased inhibition of memory traces (with heterogeneous as well as homogenous interference) appeared in significant reduction of the amount of retrieved information (50% in a 10-word memorization task, 60-70% in a short stories memorization task and 30% in memorization of two groups of three-word tasks).
- Visual memory was impaired less; however, there was a reduced amount of retrieval (four out of six figures retrieved) together with intact ability to memorize images after copying.
- Remembering experiences: there was a mild impairment in autobiographic memory, as well as in semantic memory (retelling of book plots is practically impossible for the patient).
- Abnormal inertia of memory traces appeared in perseverations of already memorized information (relevant as well as irrelevant or mistaken information).

We also identified difficulties in understanding metaphorical and hidden meanings of proverbs and series of image narratives.

Gnosis, formal thinking, programming, behavioral regulation and process of categorization were intact. The results of the neuropsychological assessment are presented in tables 1 and 2.

Thus, central neuropsychological impairment was shown in moderate impairment of different memory types: modal nonspecific impairment with mild but persistent impairments in autobiographic and semantic memories. Memory impairments appeared on the level of separate operational elements of the memorization task, as well as on the level of memorization activity as a whole. The principal mechanisms of memory impairment were (a) increased inhibition of memory tracers due to the impact of interference, (b) difficulties of selectivity of memory

Table 1

Neuropsychological Assessment (Luria Battery)

Test	Results
Sequential motor task (Luria's Fist-Edge-Palm Test)	Right hand: normal Left hand: delayed formation of movement sequence; verbal regulation is necessary
Asymmetrical movements	Difficulties in program modification
Head spatial orientation and movements	Normal
Conflict solving	Normal
Visual gnosis	Normal
"Blinded clock" (visual-spatial analysis)	5 of 5 tasks are correct
Elementary arithmetic tasks	Needs help
Acoustic gnosis	Normal
Shultz tables, 3 tables	40 sec; 47 sec; 41 sec
Serial 100-7s subtraction	5 correct subtractions
Memory: two short stories 1st story. Involuntary memorization Immediate recall Delayed recall	 4 of 8 significant details (1 false memorization) 3 of 8 significant details (2 false memorizations)
2nd story. Voluntary memorization Immediate recall Delayed recall	11 of 16 significant details 11 of 16 significant details (2 false memorizations)
Visual memory, 5 figures	Correctly recalled 4 figures of 5 immediately and after interference
Memory: 2 groups of words, 6 words total Immediate recall Delayed recall	 6 of 6 words 4 of 6 words (normal)
Autobiographical memory	Had some difficulties recalling dates of birth of his two sons and wife
Categorization test (5 tasks)	5 of 5 are correct
Verbal fluency (1 min)	11 words
Picture arrangement task	Is unable to find the correct order of pictures

Table 2

Memorization of Ten Words

Repetition	"ball"	"cry"	"sleep"	"shadow"	"flag"	"light"	"caviar"	"axe"	"hammer "	"brother"	False memorizations
1st	1*	2	3.**			6	4	5			
2nd	1	5			8	2.	3	4	7	6	
3rd	1	2				3.	5.	4	6	7	
4th	1	2	3			4.	5	6	7	8	
5th	1	2	3		8		4	5	6	7	"color"
Delayed recall (40 min)					1.	2			4	3	"cinema", "bush", "branch"

Note. * *— order of recall is indicated by numbers.* ** *— dots indicate repetitive recalls, which are interpreted as perseverations*

traces related to past experience and (c) abnormal inertia of memory processes. Moreover, the elementary level of memory processes, which is not mediated by semantic organization of information, was more severely impaired. The semantic organization of information improved the retrieval but only in the case of small amounts of information.

Results

Considering the above information and the patient and his family's requests, we discussed the rehabilitation procedures to ameliorate the efficiency and accuracy of memorization. The patient had some resources for memory rehabilitation. These resources appeared in his capacity to rely on intact elements of the memorization process: semantic organization of information and relative efficacy in remembering small amounts of information.

Rehabilitation

With L. and his wife, we discussed possible goals and objectives of rehabilitation with a neuropsychologist. To summarize, the request was to ameliorate cognitive functioning — in particular the memory process, with the goal of returning to professional activity and family life in the future. Apparently, this patient will not be able to return to his previous professional responsibilities (i.e., working with high voltage), since they were related to significant life and health risks for himself and others. At the same time, he can perform more less risky jobs with less responsibility. As L. and his wife discussed the rehabilitation process, they came up with the idea of working as a storekeeper in the same organization where L. worked before

the traumatic brain injury. This job requires an ability to work with texts of different lengths, and analysis and memorization of information without pressure to work quickly with the documents. However, neither he nor his family members expressed strong motivation towards L's return to professional activity. Mostly they wished L. could be more independent and engaged in family routines. In this context, memory rehabilitation remained one of the key requests.

From an organization point of view, time limit was important for the rehabilitation process: L. came to Moscow only for 3 weeks. Thus, we had an opportunity to conduct nine rehabilitation sessions. We formulated the following rehabilitation goal: *in 3 weeks L. will master the algorithm and rules of working with texts.*

The first three sessions were dedicated to selection of optimal (considering the time limit) amounts of text and optimal algorithms for working with text. As a result, the optimal text amount was 20 phrases so the patient could perform all the work with the text during one session (since L. worked rather slowly, longer texts took longer and increased the session time).

Table 3

Various Methods of Text Memorization

		Amount of retrieval	**Number of errors**
#1	Writing down pieces of text which come to mind on separate pieces of paper. The order of these pieces can be random. After that, the text pieces are put in correct order. Thus, the patient manipulates pieces of text which are all visible and in front of him.	–	–
#2	Narrating the text from different perspectives or roles (reading the text, L. should have paid attention to the storylines of all characters to be able to narrate the storyline of each personage).	–	–
#3	Writing the key thoughts on each piece of text ("What is it about"?) and then making a plan of narration. The narration of the text was done three times: after the first reading, after writing down the key ideas and after making a narration plan.	+	–
#4	Narrating the text and answering the psychologist's questions. In parallel to correcting the errors (gaps, mistakes of facts, false memorizations), the patient performed the "correction of the errors" task. On a piece of paper, he wrote down the errors he made, each in one of three columns (1 — gaps, 2 — mistakes of facts, 3 - false memorizations) and corrected them: inserted the missing elements in the gaps, he wrote down the false-memorization errors and mistakes of facts.	+ –	–
#5	Finding keywords and writing them down on a separate piece of paper.	++	–
#6	#5 plus error correction: including the correct answers in the narration of the text (in written form)	++	+

During neuropsychological rehabilitation, we selected the optimal algorithm for working with text (see Table 3), which we found only on the fourth session. It consisted of searching the keywords and copying them on a separate piece of paper. At first, independent search of keywords caused significant difficulties (L. even announced that to the psychologist). However, step-by-step, the process of learning evolved and L. became more and more successful and independent at performing that task. This method was the most effective and significantly increased the amount of retrieved information (see Table 4).

Table 4

Efficacy of Different Methods of Text Memorization: Amount of Information Recall

Session	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Method	**#1, #2**	**#3**	**#4**	**#5**	**#5**	**#6**	**#6**	**#6**	**#6**
1st narration (not using the method)	40%	37%	45%	37%	46%	53%	75%	50%	59%
2nd narration	40%	41%	50%	84%	85%	88%	100%	100%	100%
3rd narration	30%	61%	55%	–	–	82%	100%	–	–
4th narration	50%	–	–	–	–	–	–	–	–
5th narration	30%	–	–	–	–	–	–	–	–
6th narration	61%	–	–	–	–	–	–	–	–

Table 5

Efficacy of Different Methods of Text Memorization: Factual errors

Session	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Method	**#1, #2**	**#3**	**#4**	**#5**	**#5**	**#6**	**#6**	**#6**	**#6**
1st narration (not using the method)	4 (2/2)*	2 (1/2)	3 (2/1)	2 (0/2)	6 (3/3)	6 (2/4)	2 (2/0)	0	7 (2/5)
2nd narration	0	2 (1/1)	0	2 (0/2)	2 (0/2)	2 (2/0)	6 (2/4)	0	0
3rd narration	0	7 (5/2)	1 (0/1)	–	–	1 (0/1)	1 (0/1)	–	–
4th narration	2 (0/2)	–	–	–	–	–	–	–	–
5th narration	1 (1/0)	–	–	–	–	–	–	–	–
6th narration	0	–	–	–	–	–	–	–	–

*Note. *The number of all errors made (including significant errors of facts, perseverations and false memorizations)*

At the same time, the problem with qualitative errors in memorization was not solved. L. had confabulations and significant confusions of facts. The method of "keywords" and work on "correction of the errors" (a repeated recording of errors) did not solve the problem. As a result, after the sixth session, we changed the algorithm and principles of work with qualitative errors (see Table 5).

The sequence of "correction of the errors" changed its place in the algorithm: in the fourth to fifth session it was conducted after the first text retelling, based on the text's content; beginning from the sixth session, the "correction of the errors" was performed on errors which were made during the text retelling based on the keywords.

One of the important discoveries we made during the work on decrease of qualitative errors was that correction of these errors was done by putting correct answers in the retold text and not by copying the incorrect answers and changing them to correct ones in a separate table. As seen in Table 4, it allowed the patient to significantly decrease the number of such errors (0 errors during the last 2 sessions). Also, during the eighth to ninth sessions, L. received a printed algorithm with detailed instructions on keyword extraction.

It should be mentioned that during the last two sessions L. worked well and independently. If we had an opportunity to continue the rehabilitation, its objective would be to automatize the skills he had already developed. These skills helped him to work productively with the text.

Discussion

The main objective of the patient's rehabilitation was to return him a way of working with his own memory, with the sort of information which he would probably have to analyze, familiarize himself with and remember for his new professional activities and productive family life. In other words, the objective was to help him reconstruct his cooperation with himself.

Apparently, the search for the optimal means to help patients rebuild such cooperation takes time. In our case, it took four sessions to find a way to help him organize the information that would fit into the patient's subjective configuration. Moreover, finding this optimal method was just the beginning of the rehabilitation: we further needed to teach L. how to use that mean or method and, if possible, automatize the whole process. As seen in Tables 2 and 3, this process of learning and automation took several sessions. However, at the end of rehabilitation (as we already mentioned, the rehabilitation was limited in time because of external factors), we could talk only about relative automation of algorithm and method use. That is, it was an independent, but extended manipulation with the keywords.

According to L.S. Vygotsky's approach, during the rehabilitation we launched only the process of interiorization of a new functional system. Only a few elements of this system became automated. At the same time, due to the beginning of the interiorization process, the speed, independence and amount of retrieved information increased. In general, however, the memorization process as a new functional system is still exteriorized. To work with the text, the patient still needs some notes

in front of him. Moreover, the productiveness of the first retrieval of information is still modest (but significantly higher than before rehabilitation).

A significant decrease in qualitative errors (false memorizations, perseverations and gaps in significant details) during the adaptation of a new algorithm of memorization also signifies that the interiorization process was launched. Thus, during rehabilitation, a new functional system was developing, using some new supportive means (Vygotsky, 1997). This functional system was directed towards working with text information to analyze, understand and memorize it.

Analysis of mistakes made during the rehabilitation process and their correction are very interesting and important for us. As seen in the Results section, the biggest difficulty our patient had was to decrease the number of quantitative memorization errors: false memorizations, perseverations, gaps and significance of the story plot. The method we used first — writing down incorrect and correct answers — did not lead to improved performance. Moreover, sometimes it even led to the persistence of errors. The successful method was the one directed towards the correction of errors in the text by including correct answers in it.

This mistake we made is important to discuss for several reasons. Firstly, this mistake is quite common: since school we have been taught to "correct the errors" we have made, using an algorithm which has little effectiveness for healthy people and is not effective for patients. This algorithm is based on reproduction of an error before correcting it. Secondly, it is important to pay attention to the mechanism of memory impairment itself and the patient's mental activity as a whole. Thirdly, it is necessary to explain the physiological basis of the mechanism (described by Russian scientists such as I.P. Pavlov and A.R. Luria) which caused the impairment, and of the algorithm to overcome this impairment.

As we mentioned above, L. made memorization errors during the narration of stories. These errors were related to *impairment of selectivity* of memory traces (false memorizations) and to impairment of flexibility of neural processes caused by the mechanism of *abnormal inertia*. Together these two mechanisms aggravated memory impairment. This aggravation showed itself when our patient inertly reproduced his own errors.

Selectivity of mental processes is based on the physiological "law of strength" (Pavlov, 2011). This law states that it is possible to define a dominant system of arousal. The preservation of this law allows activation of systems of strictly selective connections, at the same time inhibiting irrelevant connections which do not correspond to a patient's objectives (Luria, 1976). If the optimal level of cortical tone is changed, its arousal decreases; the inhibitory or phasic state of the cortex develops. During this state, characterized by lower arousal of the cortex, the "law of strength" is broken (Pavlov, 1928): in primary stages, weak stimuli are equalized with strong stimuli (Pavlov described this state as an "equalizing phase"); during the deepest "equalizing" phase of the cortex even the weakest stimuli are still evoking reactions, while strong stimuli lead the cortex towards the state of strong inhibition and do not evoke any reactions.

The decrease of cortex arousal eliminates the most important condition for selectivity of mental processes and violates the main requirement of the memorization process: such "equalizing" phases of the cortex easily lead to impairment

of selectivity of relevant memory traces. In line with relevant memory traces, irrelevant connections are also activated. If the cortex tone is optimal, the irrelevant connections are inhibited. If the cortex tone is inhibited, the irrelevant connections are balanced with relevant ones; moreover, they inhibit the activation of relevant connections. That is why the irrelevant connections (stimuli) appear automatically and uncontrollably.

Another important mechanism of memory impairment — the impairment of flexibility of neural processes — manifests itself as abnormal inertia and perseverations. When cortex activity is optimal, the activation of memory traces is organized in temporal sequence: the traces are activated successively. To activate relevant connections, a person must inhibit the traces of previous connections and switch from one trace to the others. Such flexibility of neural processes is impaired in the case of brain injuries. The traces, activated in the cortex, become abnormally inactive, which means that normal shifting from one memory trace to the others is impaired.

Thus, to overcome (or prevent) qualitative memory errors, it was important to account for the specificities of our patient's neurodynamic balance, which were diagnosed during the neuropsychological assessment. The patient should have been placed in a situation in which an error (weak stimuli) could not be "activated" as an irrelevant connection. The similar logic of a rehabilitation program can be seen in such well-recommended approaches as errorless learning (Fish, Manly, Kopelman, & Morris, 2015; Roberts et al., 2016; Wilson, 2013), avoiding possible activations of any irrelevant connections and repeated fixation of relevant stimuli which, according to laws of abnormal physiology, evoke weak reactions.

Conclusion

In healthy people, the amount of memory traces accessible for retention is increased if they are successfully coded. In other words, the amount of retention of memory traces increases if these traces are included in systems of meanings. Numerous researchers also mentioned this, while K. Bulher (Innis, 2013) supposed that the "memory of thoughts" is much larger than the "memory of elements". Vygotsky, Leont'ev, Luria and others stated the same. This translation of memory processes on a higher level (which actually is the process of semantic organization of memory) significantly increases the amount of memories retrieved and reinforces the stability of memory traces.

The method of finding keywords in the text was the most effective method in our patient's rehabilitation. While the patient was mastering and automatizing it, the method caused a significant increase of the productivity of memorization. In other words, this method actually is one of the well-known methods widely used in different life domains, such as education and health: the method of meaningful organization of information. Combining this method with accounting for the specificities of neurodynamic balance and correcting of memorization errors allowed us to significantly increase the efficiency and accuracy of our patient's memorization. It also gave him a metacognitive strategy as an instrument to work with his own memory.

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