MODELING CONNECTIONS OF SEMANTIC FIELDS IN MENTAL LEXICON

Dr. Prof. Elena Erofeeva[1]

Dr. Prof. Konstantin Belousov[1]

PhD, Associate Prof. Yuliya Leshchenko[1]

[1] Perm State National Research University, Perm, **Russia**

ABSTRACT

Mental lexicon is a complex system that reflects in a linguistic form the processes of cognition and structuring the surrounding reality. Mental lexicon can be represented in form of a multidimensional network; its structural units are nodes (fragments of information fixed in individual consciousness) and internodal connections (ways of these elements' interaction). Internodal connections can have different direction and diverse activation levels. The strongest connections are the semantic ones. They form semantic subnetworks that can be treated as analogues of semantic fields in mental lexicon. The paper tests the hypothesis that semantic fields (subnetworks) are interconnected by way of connections of their units. The method of directed chained associative test (with a chain of not less than 30 reactions) was used in the research. The research material is represented by reactions' chains received from 139 informants (the total of 4334 reactions). The material was processed in the "Semograph" Information System (semograph.com) that gives a possibility to create semantic classification of reactions with many-to-many correspondence between reactions and fields. The sequence of activating semantic fields in reactions' chains was analyzed. The received data confirm the hypothesis that mental lexicon units are grouped according to the field principle. In this context separate fields due to the connections of their units are more closely interconnected with each other than with all other fields. The activation of the fields' connections has a directed character.

Keywords: mental lexicon, structure, subnetwork, semantic field, connections

INTRODUCTION

Mental lexicon is a complex formation which represents in individual consciousness the linguistic system of a certain language, reflects the processes of cognition and structuring the surrounding reality, and determines all speech processes [1], [2], [3] etc. Mental lexicon represents an integral part of a person's language capacity which is directly connected to one's conceptual and categorical systems; in a certain way it can be defined as a specific zone of interaction of language and cognition [4].

Current research of mental lexicon structure and functional characteristics is developed in the frameworks of the connectionist theory which represents mental lexicon in form of a complex multidimensional network [5]. Basically, network models of mental lexicon reproduce the structure and/or functional aspects of biological neural networks (neural networks of human brain) which fix any cognitive experience of an individual, including the experience connected with language acquisition.

According to the network metaphor, structural units of mental lexicon include nodes (fragments of information fixed in individual consciousness) and internodal connections (specific links that reproduce distinct ways of how these fragments of information can interact with each other). Internodal connections in mental lexicon can have different direction and diverse activation levels. Various models of mental lexicon (including those of bilingual and multilingual speakers) take into account different types and directions of internodal connections, as well as discriminate certain subnetworks within the holistic unified network [6, 7].

Subnetworks in mental lexicon are formed by elements united to each other by ways of connections of similar type. Depending on what kind of connections is focused on by a researcher (phonological, orthographical, morphological, semantic, syntactic, etc.) different subnetworks can be distinguished. We assume that semantic connections that form semantic subnetworks are the strongest ones in mental lexicon. These subnetworks can be treated as analogues of semantic fields – arrays of linguistic units conjoined by a commonness of their content that reflect conceptual or functional similarity of the phenomena they denote [8].

SUBJECT, MATERIAL AND METHODS OF THE RESEARCH

The paper describes a research aimed at testing the following hypothesis: semantic fields represented in mental lexicon subnetworks are interconnected with each other via the connections of their units; connections between fields determine the basis of the network structure. The subject of the research is modeling the system of connections between semantic fields in mental lexicon.

The research material is a set of associative chains received in the directed chained associative test carried out while studying an image of professional activity of the informants different specialties (for more detail see [9]). The instruction received by the informants ran as follows: “Make a list of not less than 30 words, word combinations or phrases that characterize your PROFESSIONAL ACTIVITY from different perspectives”. The informants (139 people) were representatives of three specialties (linguists, physicists, medical professionals) of different age and qualification. As a result 4 334 reactions were received.

Field analysis and statistical analysis were used as research methods.

While carrying out field analysis the following principles were adhered to: 1) classification was realized by some experts (a concerted opinion on controversial points was worked out); 2) each semantic field is constituted by a multitude of linguistic units which meanings have a common semantic component (the field name is given in accordance with the common semantic component); 3) one linguistic unit could be included into more than one semantic field; 4) word combinations consisting of two or more components are referred to two or more semantic fields (e.g., *богатый лексикон* ‘a rich lexicon’ was simultaneously included both in the SPEECH ACTIVITY and EMOTIONAL AND EVALUATIVE SPHERE fields); 5) in case a polysemantic word occurs in reactions’ chains in different meanings or its meaning is not clear from the context, it was referred to both correspondent semantic fields (e.g., *словарь* ‘a dictionary’ was simultaneously included into the INSTRUMENTS and RESULTS OF SCIENTIFIC ACTIVITY fields); 6) statistical index was used as the major criterion of singling out the semantic fields.

Field analysis was carried out in the "Semograph" Information System (semograph.com) that gives a possibility to create semantic classification of reactions with many-to-many correspondence between reactions and fields. Further on the sequence of activating semantic fields in reactions' chains was analyzed and statistical analysis of "shifts" between fields in reactions' chains was realized.

RESULTS

As a result of field analysis of reactions received in the experiment 29 mutually interconnected semantic fields were singled out. The fields and their size (the quantity of reactions referred to each field in absolute values) are shown in Figure 1.

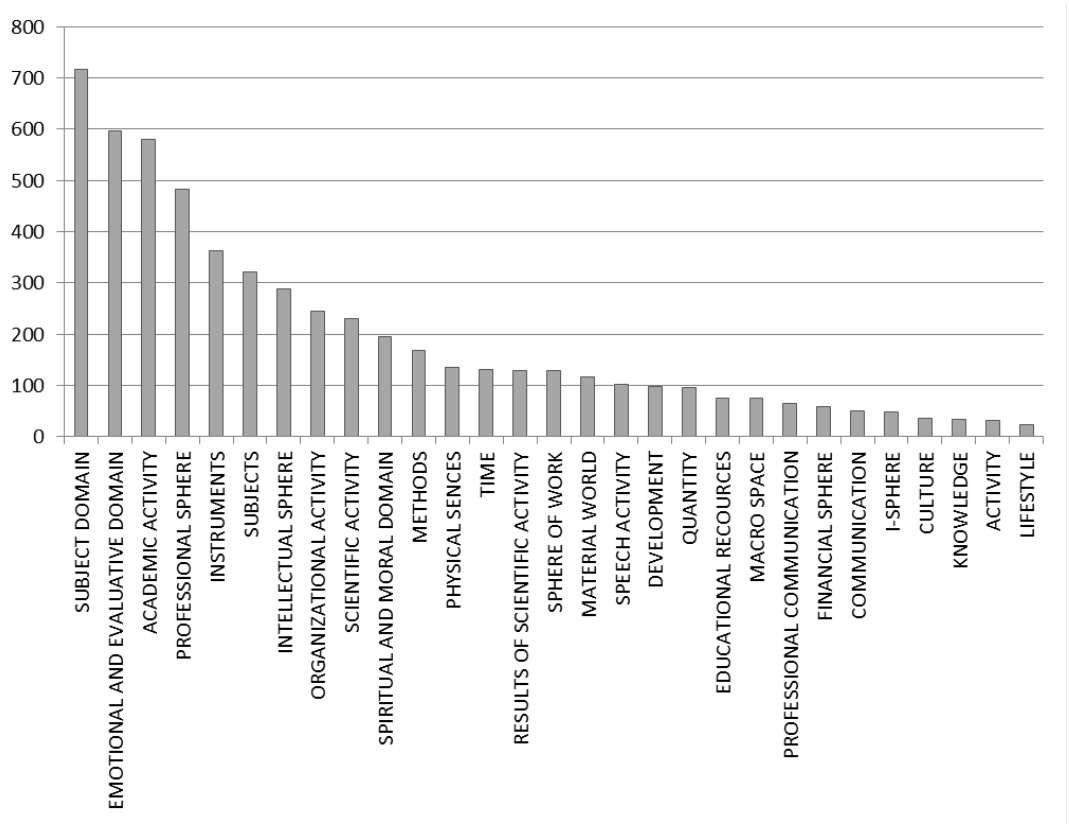

Figure 1. Semantic fields and their size, abs.

As we can see, the most frequent reactions in the experimental material are those that belong to the semantic fields SUBJECT DOMAIN, EMOTIONAL AND EVALUATIVE DOMAIN, ACADEMIC ACTIVITY, and PROFESSIONAL SPHERE. These fields constitute the nucleus of the image of a professional activity of the informants (inclusion into the nucleus of the ACADEMIC ACTIVITY field is determined by the fact that a larger part of the informants are university teachers which was conditioned by another task of the research). The pre-nuclear zone is formed by the fields INSTRUMENTS, SUBJECTS, INTELLECTUAL SPHERE, ORGANIZATIONAL ACTIVITY, SCIENTIFIC ACTIVITY, SPIRITUAL AND MORAL DOMAIN, METHODS. The other fields are small in size and constitute the periphery of the image of a profession.

The biggest in size semantic fields (the nucleus and the pre-nuclear zone) include one fourth (75%) of all the reactions of the informants; these fields particularly are most

interesting from the point of view of shifts from one field to another within the sequel of an associative row.

While analyzing reactions' chains of every informant we took into account not the concrete reaction, but the semantic field to which it belongs. As a result we built up a matrix of "shifts" between fields in associative rows.

By a "shift" between fields we mean a sequence of fields wherein reactions following each other in an associative row belong. There are two types of the sequence of associations in an associative chain: 1) one association belongs to a SEMANTIC FIELD$_1$, while the following association belongs to a SEMANTIC FIELD$_2$ (i.e., a shift of field occurs); 2) two successive associations belong to the same semantic field (i.e., no shift of field is observed). We define the latter case as an absence of shift or a field repetition.

A fragment of the matrix that includes most frequent fields mentioned above is presented in Table 1 (the data of the full matrix including the periphery fields will be described further). The cells of the matrix show frequencies of shifts from SEMANTIC FIELD$_1$ (table rows) to SEMANTIC FIELD$_2$ (table columns) within the whole total of the experimental material. The beginning of an associative chain is a shift from the field START to the following field.

Table 1. Matrix of shifts from SEMANTIC FIELD$_1$ to SEMANTIC FIELD$_2$ in the chained associative test, abs.

	SEMANTIC FIELD 2											
SEMANTIC FIELD 1	START	SPIR.-MORAL DOMAIN	INSTRUMENTS	INTELLECT.SPHERE	METHODS	SCIENTIF. ACTIVITY	ORGANIZ. ACTIVITY	SUBJECT DOMAIN	PROFESS. ACTIVITY	SUBJECTS	ACADEMIC ACTIVITY	EMOT.-EVAL.DOMAIN
START	0	12	17	14	5	15	9	39	20	10	27	34
SPIR.-MORAL DOMAIN	0	44	4	19	3	4	9	7	18	15	12	67
INSTRUMENTS	0	2	104	16	17	12	16	56	39	9	42	14
INTELLECT.SPHERE	0	20	11	43	13	11	12	25	19	15	33	59
METHODS	0	2	19	12	26	10	13	33	27	10	9	8
SCIENTIF. ACTIVITY	0	4	13	15	10	43	23	27	25	15	41	9
ORGANIZ. ACTIVITY	0	5	20	10	5	20	52	13	38	12	50	15
SUBJECT DOMAIN	0	4	55	32	43	29	14	355	37	37	73	28
PROFESS. ACTIVITY	0	24	40	20	26	16	23	39	128	47	37	78
SUBJECTS	0	8	16	21	7	14	24	33	39	88	40	49
ACADEMIC ACTIVITY	0	12	42	31	15	43	41	73	35	36	184	46
EMOT.-EVAL.DOMAIN	0	61	15	66	8	12	17	30	67	48	35	202

According to the matrix data the "starting fields" can be singled out in the materials of a chained associative experiment. Reactions from these fields most often function as the

starting ones for an associative row (see the cells at the intersection of the line START with the columns of the matrix). In most cases the informants start an associative chain with reactions belonging to the semantic fields SUBJECT DOMAIN, EMOTIONAL AND EVALUATIVE SPHERE and ACADEMIC ACTIVITY that form the nucleus of a professional activity image. Less often (though frequently enough) an associative chain begins with reactions belonging to the fields PROFESSIONAL SPHERE and INSTRUMENTS that form the pre-nucleus zone. Particularly these semantic fields have the largest size in the structure of a professional activity image. Thus, our experimental material proves the existence of positive correlation between a field size and the belonging of the first reaction in an associative chain to this field.

Although the major part of shifts between fields is not realized at all in the experimental material (among 1160 cells of the full matrix 158 cells equal zero that amounts to over 13%), there is no field that never evokes any shifts, as well as no field that is never shifted to. This means that all the fields are one way or another interconnected into a single network via the connections of their elements.

Given below, there is a table of frequencies of repeating a certain field, of shifting from this field to another one, and of shifting from another field to the given one (Table 2).

Table 2. Size of fields and frequencies of shifts between fields, abs.

Semantic field	Size	Repetition of a field	A shift from a field	A shift to a field
SUBJECT DOMAIN	717	355	465	492
EMOTION.- EVALUAT. DOMAIN	597	202	597	632
ACADEMIC ACTIVITY	579	184	553	584
PROFESSIONAL SPHERE	482	128	518	535
INSTRUMENTS	362	104	314	347
SUBJECTS	322	88	346	365
INTELLECTUAL SPHERE	288	43	296	359
ORGANIZATIONAL ACTIVITY	245	52	290	294
SCIENTIFIC ACTIVITY	230	43	266	255
SPIRITUAL-MORAL DOMAIN	195	44	215	213
METHODS	169	26	175	180
PHYSICAL SENSES	136	25	158	148
TIME	131	24	176	186
RESULTS OF SCIENTIF. ACTIVITY	129	25	130	139
SPHERE OF WORK	128	29	136	136
MATERIAL WORLD	117	23	132	128
SPEECH ACTIVITY	101	10	120	122
DEVELOPMENT	98	13	133	130
QUANTITY	96	15	143	144
EDUCATIONAL RESOURCES	76	8	85	90
MACROSPACE	74	10	88	98
PROFESSIONAL COMMUNICATION	65	3	91	101
FINANCIAL SPHERE	58	4	74	78
COMMUNICATION	50	3	73	72
I-SPHERE	49	8	75	76
CULTURE	36	0	47	30
KNOWLEDGE	34	3	45	42
ACTIVITY	31	2	35	38
LIFESTYLE	23	0	25	34

The mean absolute value of frequency of field repetition at the given sample amounts to 50.8, while the mean value of a field shift into any other field amounts only to 7.2. Consequently, we come to the conclusion that while generating an associative chain it is easier for the informants to produce a reaction that belongs to the same field as the previous one, than to make a shift from one field to another.

In most cases the ensuing reaction belonging to the same field as the previous one is produced after the reactions belonging to the SUBJECT DOMAIN field; further on in descending order there follow the fields EMOTIONAL AND EVALUATIVE DOMAIN, ACADEMIC ACTIVITY, PROFESSIONAL SPHERE and INSTRUMENTS (see Table 2). Thus, a field size also turns out to be the most important feature: the bigger is the size of a semantic field activated in the associative experiment, the higher the probability that two consecutive associations in the chain will belong to this field.

Nevertheless, for reactions from some fields belonging to the pre-nucleus zone or to the periphery of an image of a profession this regular pattern may not be observed. Thus, reactions belonging to the semantic fields CULTURE and LIFESTYLE are never followed by other reactions from the same fields (the frequency of repeating the field equals to zero); reactions from the fields ACTIVITY, PROFESSIONAL COMMUNICATION, SPIRITUAL AND MORAL DOMAIN, PHYSICAL SENSES, EDUCATIONAL RESOURCES are more often followed by reactions from other semantic fields than from the same ones (here we mean frequencies of shifts to separate fields, not the total amount of shift frequencies into other fields). For example, most often reactions from the fields ACTIVITY, SPIRITUAL and MORAL DOMAIN, PHYSICAL SENSES are followed by reactions from the field EMOTIONAL AND EVALUATIVE DOMAIN (the frequencies are 12, 67 and 36 accordingly); reactions from the field PROFESSIONAL COMMUNICATION are followed by reactions from the fields ORGANIZATIONAL ACTIVITY (13) and RESULTS OF SCIENTIFIC ACTIVITY (12); reactions from the field EDUCATIONAL RESOURCES are followed by reactions from the field ACADEMIC ACTIVITY (20). Thus, we observe differences of associative strategies that characterize shifts semantic fields of different size.

In most cases shifts to other fields are observed from the following ones: EMOTIONAL AND EVALUATIVE DOMAIN, ACADEMIC ACTIVITY, PROFESSIONAL SPHERE, SUBJECT DOMAIN, SUBJECTS, INSTRUMENTS, INTELLECTUAL SPHERE, ORGANIZATIONAL ACTIVITY, SCIENTIFIC ACTIVITY, SPIRITUAL AND MORAL DOMAIN. As for shifts from other fields, they occur most frequently into the same fields mentioned above (see Table 2). The frequency of shifts from other fields and to other fields does not exceed 200. As we can see, the list of fields from which and to which the shifts occur, is identical (only the position of two fields in the list is changed).

Table 3 lists the most frequent scenarios of shifts from each particular field. The analysis of concrete shifts from one field to another shows that the most frequent shifts are the following: PTOFESSIONAL SPHERE → EMOTIONAL AND EVALUATIVE SPHERE (78); SUBJECT DOMAIN → ACADEMIC ACTIVITY (73); SPIRITUAL AND MORAL DOMAIN → EMOTIONAL AND EVALUATIVE SPHERE (67); EMOTIONAL AND EVALUATIVE SPHERE → INTELLECTUAL SPHERE (66); INTELLECTUAL SPHERE → EMOTIONAL AND EVALUATIVE SPHERE (59);

INSTRUMENTS → SUBJECTDOMAIN (56). We can observe that in the majority of cases the most frequent shifts are not symmetrical. Thus, for example, the SUBJECT DOMAIN field most often shifts into the EMOTIONAL AND EVALUATIVE DOMAIN, while the EMOTIONAL AND EVALUATIVE DOMAIN field most often shifts into the INTELLECTUAL SPHERE field, but not into the SUBJECT DOMAIN one. Consequently, connections between different fields in mental lexicon can basically be characterized as asymmetrically directed.

Table 3. Most frequent scenarios of shifts from semantic fields, abs.

Semantic field$_1$	→ Semantic field$_2$	Shift frequency
PROFESSIONAL SPHERE	→ EMOTIONAL AND EVALUATIVE D.	78
SUBJECT DOMAIN	→ ACADEMIC ACTIVITY	73
SPIRITUAL AND MORAL SP.HERE	→ EMOTIONAL AND EVALUATIVE D.	67
EMOTIONAL AND EVALUATIVE D.	→ INTELLECTUAL SPHERE	66
INTELLECTUAL SPHERE	→ EMOTIONAL AND EVALUATIVE D.	59
INSTRUMENTS	→ SUBJECT DOMAIN	56
ORGANIZATIONAL ACTIVITY	→ ACADEMIC ACTIVITY	50
SUBJECTS	→ EMOTIONAL AND EVALUATIVE D.	49
ACADEMIC ACTIVITY	→ EMOTIONAL AND EVALUATIVE D.	46
SCIENTIFIC ACTIVITY	→ ACADEMIC ACTIVITY	41
PHYSICAL FEELINGS	→ EMOTIONAL AND EVALUATIVE D.	36
METHODS	→ SUBJECT DOMAIN	33
MATERIAL WORLD	→ INSTRUMENTS	29
TIME	→ EMOTIONAL AND EVALUATIVE D.	28
QUANTITY	→ EMOTIONAL AND EVALUATIVE D.	24
DEVELOPMENT	→ EMOTIONAL AND EVALUATIVE D.	24
EDUCATIONAL RESOURCES	→ ACADEMIC ACTIVITY	20
I-SPHERE	→ EMOTIONAL AND EVALUATIVE D.	18
SPHERE OF WORK	→ ACADEMIC ACTIVITY	17
RESULTS OF SCIENTIFIC ACTIVITY	→ SCIENTIFIC ACTIVITY	14
SPEECH ACTIVITY	→ SUBJECT DOMAIN	14
PROFESSIONAL COMMUNICATION	→ ORGANIZATIONAL ACTIVITY	13
ACTIVITY	→ EMOTIONAL AND EVALUATIVE D.	12
MACRO SPACE	→ EMOTIONAL AND EVALUATIVE D.	11
COMMUNICATION	→ EMOTIONAL AND EVALUATIVE D.	10
KNOWLEDGE	→ SUBJECT DOMAIN	8
FINANCIAL SPHERE	→ PROFESSIONAL SPHERE	7
CULTURE	→ PROFESSIONAL SPHERE	6
LIFESTYLE	→ EMOTIONAL AND EVALUATIVE D.	6

CONCLUSION

The analysis of reactions' chains received in a directed associative experiment lead to the following conclusions about connections of semantic fields in mental lexicon.

It is easier for the informants to produce consecutive reactions belonging to the same semantic field than to make shifts between fields. Nevertheless, from this point of view different fields are not similar in the consciousness of the informants: reactions from some fields are seldom or never followed by other reactions from the same fields.

The fields that are biggest in size are most active in all types of shifts that is the natural consequence of the fact that they include the largest number of units.

The quantity of shifts from a field to some other fields (in total) and to a field from some other fields (in total) is always larger that the quantity of shifts within a field. Evidently, this fact in particular determines the connectivity of the whole network.

In case of middle-size and small fields the number of shifts from a field to some other fields and to a field from some other fields (in total) is by several times larger than the shifts within a field; this determines the possibility for these fields to be included into the general network.

There are several combinations of fields that are standard for the informants. These are the cases when a reaction from one field is followed by a reaction from another field; however, the reverse is not true. This can be explained by the asymmetric character of the direction of fields' activation.

The received data prove the research hypothesis: mental lexicon units are organized according to the field principle; along with it certain fields are more closely connected with each other than with all other fields via the connections of their units. This consistent pattern enables to distinguish certain subnetworks of semantic fields within the unified mental lexicon network. We assume that studies of semantic fields' subnetworks as relatively coherent structural units open new perspectives in mental lexicon research.

ACKNOWLEDGEMENTS

The authors are grateful to all the informants who took part in the study as well as to RFBR for the support of the research (projects No. 15-04-00320).

REFERENCES

[1] Zalevskaya A.A., Slovo v leksikone cheloveka. Voronezh, 1990. (in Russian).

[2] Aitchison J., Words in the mind, Oxford, Blackwell, 1994.

[3] Paivio A., Dual coding theory and the mental lexicon, The Mental Lexicon, vol. 5, issue 2, pp 205–230, 2010.

[4] Kubrjakova E.S. V poiskakh sushchnosti jazyka: Kognitivnye issledovanija. Moscow, Russia, 2012. (in Russian).

[5] Miikkulainen R., Kiran S., Modeling the bilingual lexicon of an individual subject, Cognitive Science, vol. 56, issue 29, pp 191–199, 2009.

[6] Li P., Farkas I., A self-organizing connectionist model of bilingual processing, Heredia, R., Altarriba, J. (eds.), Bilingual Sentence Processing, Amsterdam, Elsevier, pp 59–85, 2002.

[7] Li P., Zhao X., Self-organizing map models of language acquisition, Frontiers in psychology, 2013, http//journal.frontiersin.org/article/10.3389/fpsyg.2013.00828/full

[8] Shchur G.S., Teoriya polya v lingvistike, Moskva, Russia, 1974. (In Russian.)

[9] Belousov K.I., Erofeeva E.V., Erofeeva T.I., Zelyanskaya N.L., Leshchenko Y.E., University teachers of linguistics and self-image of their profession, Procedia – Social and Behavioral Sciences, vol. 214, pp 667–676, 2015. (In Russian.)