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MEANING ESTIMATION OF HUMAN SPEECH AND THOUGHT ACTIVITY

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Abstract: The relevance of the research is conditioned by the rapid development of communication relationships between people by means of speech and thought activity and computer communication means. In particular, an important role is vested in sending and relevant reception of meaning of an information message. With regard to this, the paper is aimed at revealing the criteria for estimating the meaning of human speech and thought activity and at establishing algorithmic relationships between them. The content of the paper belongs to the sphere of interdisciplinary scientific research at the confluence of the theory of information, cognitive psychology and linguistics. The leading method of research in the topic of this scientific paper is the method of information theory that allows determining the coherence of an information message using entropy. In the paper, criteria are described and an algorithm is suggested for estimating the meaning of human speech and thought activity and of an information message. The materials of the paper are of practical use for artificial intelligence developers and cognitive psychology and linguistics experts.

Keywords: Meaning, information, entropy; speech incoherence; schizophasia.

INTRODUCTION

Man sends and receives information during speech and thought activity. It is a conscious or unconscious thought activity of man during which the information is sent or received by means of speech or text. A derivative of speech and thought activity is a text information message (text) in which man inputs a meaning. It is the text information message with the meaning input in it that is the subject of this research.

Speech and thought activity (STA) plays an important part in human interaction. One of the causes of conflicts arising between people can be a misinterpreted

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information message, or, in other words, misinterpretation of meaning of the information message. The question is also relevant in psychology and psychiatry for estimating the STA of a person with a disorder of thinking, in the area of artificial intelligence, and in linguistics. However, criteria are necessary for assessing any value, meaning including. Hence the objective of the paper commended to the attention of readers is justification of criteria for estimating the meaning of human STA and, therefore, of an information message too.

Meaning is an interdisciplinary notion studied first of all in linguistics, logics, philosophy, and psychology. As a result, the idea about meaning is characterized by a great diversity and ambiguousness. So, when conducting their research, the authors set a task for themselves to find a common ground which would allow integrating various characteristics of meaning into a clear quantitative notion.

LITERATURE REVIEW

Turning to the problem of meaning, A.I. Novikov (2017), characterizes it in the following words: "Meaning belongs to the mysterious phenomena that are considered to be as if universally known, for they keep being used both in scientific and daily communication. In fact, not only no strict generally accepted definition of meaning is to be found, but also at the descriptive level there is quite a wide scatter of judgments about what the meaning actually is. Sometimes meaning is assumed to belong to those most general categories that are not to be determined and are to be perceived as a kind of granted ones. At present, due to an entire number of relevant tasks of both theoretical and applied nature where the notion of meaning is of key importance having to be solved, certain more precise definitions of the notion are required".

The New philosophical encyclopedia (Schreider, 2000) gives the following notion of meaning. "Meaning is the essence of a phenomenon in a broader context of reality. The meaning of a phenomenon justifies the existence of the phenomenon, as it determines its place in a certain integrity, introduces the "part-whole" relationships, and makes it necessary as a part of the integrity."

The imaginary or actual purpose of some things, words, notions or actions built in by a certain person or community is also called meaning. The opposite of meaning is meaninglessness, i.e. lack of a certain purpose. Definition of objectives can be understood as meaning, and so can a result of an action.

Alongside with linguistics (Suleimenova, 1989) (hereinafter examples of reference sources are cited that do not exhaust the entire diversity of literature on this topic), logics (Frege, 1997; Deleuze, 1995), philosophy (Lankin, 2003), and psychology (Leontiev, 2007) are also interested in meaning. At the center of interests of all these subjects, there is language and its relation to thinking, on the one hand, and to reality – on the other. However, each of the subject sees its own

interest in this problem. As a result, the idea about meaning is characterized by a great diversity and ambiguousness.

Logical and philosophical works and linguistic studies use different characteristics of meaning. The common intersection point in the diverse published works can be considered the fact that meaning is correlated with information and knowledge. However, for the logical and philosophical approach, it is characteristic to correlate the information and knowledge with conceptual systems, structures of knowledge, social and individual experience of an individual. The linguistic approach relies on the idea about meaning being directly contained in an utterance, in a text, so comprehending a meaning appears to be similar to a computational process.

Meaning is also studied by ontology (Sergeev, 2009), theory of cognition (Abachiev, 2013) and methodology of science (Kulikov, 2005). In ontology, meaning-related coordinates of being are considered. In theory of cognition, the problem of meaning is a part of the range of problems of nature and sources of knowledge, in particular, of the boundaries of its meaningfulness and meaninglessness. Within methodology, the applied characteristics of a scientific method are revealed and new problem situations are discussed; otherwise the introduction of a new method is considered to lack meaning.

Studying the problem of understanding in philosophy, S.S. Gusev and G.L. Tulchinsky (1985), cite the words of M.B. Creelman, an American psychologist: "…Meaning is like a mysterious Cinderella, it remains unrecognized and elusive. One of the difficulties here may lie in various admirers of this Cinderella fancying her each in his own way and her diversity engages them to look for her various manifestations… Some focused their attention on her intellectual qualities while others imagined her sensitive and emotional. There were also such who having reconciled the mystery veiling her agreed in advance that… she is in her essence inaccessible and unclear" (Gusev & Tulchinsky, 1985, p. 43). Though pronounced over three decades ago, these words have so far remained relevant.

Scientific research of the problem of meaning are conducted, models and methods of text analysis and revealing the meaning input in it are developed. This area is represented by the vast amount of reference works (Bezrukov, 2016; Carley, 1997; Hunter, 2014; Taylor & Wang, 2007; Turney & Pantel, 2010; Xiong & Tian, 2010; Xie et. al., 2014; Zhang et. al., 2013; Wu & Zhou, 2010). The authors also conducted a number of studies associated with information and meaning input in it (Fadyushin 2016; Fadyushin et. al., 2017), with this paper being a result of continuation of the studies.

RESEARCH METHODS

The authors believe that meaning of an information message is a human thought coded by certain language signs and reflected in oral or written form. According

to Bleicher (1983), the form of existence of thought is speech. Therefore, STA is a reflection of human thought activity.

For establishing the STA and information message meaning estimation criteria, one of the key notions of the theory of information – entropy – was used. The authors' studies (Fadyushin et. al., 2014, 2015) show that owing to entropy text can be a source of unpredictable energy. If text or oral messages had no entropy, they would not bring any news to the addressees, and therefore, they would not cause change of their emotional condition. The forces and connection of entropy and the intellect are discussed in the paper by A.D. Wissner-Gross and C.E. Freer (2013). As for the text, according to C. Shannon (1951), entropy is "a statistical parameter that measures in a known meaning the average quantity of information accounting for one letter of language text" (Shannon, 1951, p. 50).

What is the association between entropy and meaning? For answering the question, a comparative statistical analysis of two following types of texts was conducted:

1. Usual text is a text that has meaningful content. For example: "It is early autumn. The landscape is filled with a soft golden light… Keep in your soul this childish, spontaneous dreaminess – the ethereal light shining on our at times drab everyday reality with gentle rays of quiet joy" (Fadyushin, 2009, p. 117-118).
2. Probabilistic text (meaningless one) is the same usual text but with random distribution of words. For the above example, it is as follows: "It autumn is early. Golden landscape filled is soft light with… Quiet reality light our soul in gentle at times spontaneous joy dreaminess everyday childish this drab keep the ethereal rays shining on".

For each type of text, the difference of entropy of two adjacent words ΔH was calculated which is brought into consideration by the authors and adopted as characteristics of coherence of words of the information message. For ΔH as a random value, dispersion *Var* **(**ΔH**)** was calculated.

The entropy was calculated according to C. Shannon's formula (Shannon, 1948):

$$H = -\sum_{i=1}^{n} p_i \log_2 p_i, \qquad (1)$$

Here H is the entropy of a set of probabilities p_i, bit/symbol, p_i – probability of i-th symbol in the text message.

Calculations of entropy dispersion of words *Var* **(**ΔH**)** have shown that dispersion is higher for text type 1 than for text type 2. In the example considered, *Var* **(**ΔH**)** amounted to, respectively:

1. $Var\ (\Delta H)_1 = 0{,}794$ (bit/symbol)^2;
2. $Var\ (\Delta H)_2 = 0{,}698$ (bit/symbol)^2.

RESULTS AND DISCUSSION

Proceeding from the results obtained, the authors came to the following conclusion. The less ordered the text of an information message from the viewpoint of probability distribution of words is, the higher the coherence dispersion is, and vice versa. The comparison of the text information message type with the dispersion value gives grounds to suggest that the higher dispersion is, the more meaning the text has got, and conversely. In other words, the simpler an information message is compiled, the clearer it is to another person. This conclusion is in line with the well-known saying "He who thinks clearly explains clearly". This is a kind of qualitative criterion for estimating a human STA. As for the regularity revealed, it gives grounds for using the entropy dispersion of words coherence for qualitative estimation of STA meaning as criterion M:

$$M = Var(\Delta H) \tag{2}$$

Criterion M allows performing the probability estimate of meaning of a human STA. The estimate algorithm is based on comparative analysis of one and the same text message in various interpretation according to a rating scale.

In order to determine the limit values of the rating scale, the authors turned to psychiatry where anomalies in thinking are studied by analyzing the human STA. Disorders of thinking and STA are characterized by the following notions: speech incoherence and schizophasia.

Speech incoherence is a speech disorder in which grammatical relationships are wrong and speech consists of a chaotic set of words. Grammar structure is completely disordered. Answers do not correspond to questions and even a remote relationship cannot be understood in a sentence. The following fragment of speech given by V.M. Bleicher (1983) as an example (a record of a talk to a patient) illustrates the speech incoherence:

- How do you feel?
- Where is Petya… I was gone and slept. And what do they want? and yesterday it was… there is everything…
- Where are you?
- Are you… everybody is here. Put off the lights. Where is wife? Got to go… Well, and how? Lost my spectacles.

The top stage of speech incoherence ("word salad") is a set of words or even meaningless neologisms.

Schizophasia or speech disintegration is a symptom of mental disorders that manifests itself in disruption of speech structure; unlike the speech incoherence,

in it the phrases are built correctly but they have no meaning and the content of speech is that of delusion (Zhmurov, 2010). An example of such speech is given in a record transcript from the supplement to Great Medical Encyclopedia (Great Medical Encyclopedia, 1962); it is from the transcript that the following fragment is borrowed:

”Born in Herzen Street, in grocery store No. 22. A well-known economist, a librarian by his avocation. As they say, a collective farm worker. In a shop – a salesman. So to speak, necessary in the economy…”.

The following conclusion can be made from the descriptions of speech incoherence and schizophasia pertaining to the topic of this research. According to the definition, the human speech in condition of speech incoherence corresponds to the second text type (probabilistic text – nonsense). I.e. if a human speech (text) corresponds to speech incoherence, estimation criterion *M* will tend to the minimum value and point to the lack of meaning. In schizophasia, also according to the definition, the human speech corresponds to the first text type (usual text), however, with such a word order in sentences as to result in the loss of meaning. That is, if a human speech (text) corresponds to schizophasia, estimation criterion *M* will approach the maximum value and point to the lack of meaning too (or, more exactly – to the “excessive” meaning). This conclusion is graphically illustrated in Figure 1 as a rating scale for the human STA meaning.

	M = min		M = max
Speech incoherence		Norm	Schizophasia
Lack of meaning		Presence of meaning	“Excessive” meaning

Figure 1: Rating Scale of the Human STA Meaning
Source: **The Authors**

Thus, the following prerequisites underlie estimation of meaning of the human STA:

1. The meaning of an information message is estimated by entropy dispersion of coherence of the adjacent words.
2. The minimum value of the STA meaning estimation criterion corresponds to speech incoherence and gives evidence about the information message containing no meaning.
3. The maximum value of the STA meaning estimation criterion corresponds to schizophasia and gives evidence about the information message containing no meaning as well.

As for the prerequisites, it should be noted that the minimum and maximum values of the STA meaning estimation criterion correspond to speech incoherence and schizophasia but they are not the symptoms of the disorders. The psychiatric

notions were used by the authors for setting the limit values for the rating scale of the human STA meaning.

Based on the above prerequisites, the human STA meaning estimation algorithm has been developed that consists in the following:

1. For each word of the source text, entropy is calculated according to formula (1) (the minus sign is not taken into account). Next, the difference of entropies between two adjacent words is calculated that characterizes entropy coherence of the source text:

$$\boldsymbol{\Delta H_k} = |H_i - H_{i+1}|, \tag{3}$$

here $i = 1, 2, 3, \ldots, n$ is the item number of the word in the text; n is the quantity of words in the text; $k = |1 - 2|, |2 - 3|, |3 - 4|, \ldots, |(n - 1) - n|$.

2. According to expression (2), the criterion of estimation of meaning of the source information message ($\boldsymbol{M_s}$) is calculated as entropy dispersion of words coherence.
3. The source text is brought down to the probabilistic type by random relocation of words. For the probabilistic text obtained, calculations according to item 1 and 2 are repeated, and the value of probabilistic information message meaning estimation criterion $\boldsymbol{M_p}$ is found.
4. The source text is brought down to the maximum value of entropy dispersion of words coherence. For this, words in sentences are combined in such a way as to obtain the maximum range of the interval between two adjacent entropies difference values. For the obtained text, calculations according to item 1 and 2 are repeated and the value of information message meaning estimation criterion with the maximum entropy dispersion of words coherence $\boldsymbol{M_m}$ is found.
5. The meaning estimation criteria values for the source and probabilistic texts and for the one having the maximum information messages dispersion value are compared and analyzed:

   if $\boldsymbol{M_p} < \boldsymbol{M_s} < \boldsymbol{M_m}$, then, the source information message most probably contains meaning;

   if $\boldsymbol{M_p} \geq \boldsymbol{M_s} \geq \boldsymbol{M_m}$, then, the source information message most probably contains no meaning.
6. In order to estimate the text type, i.e. its corresponding to speech incoherence or schizophasia, entropy coherence values of words are calculated for the source text ΔH_k^s, for the probabilistic one ΔH_k^p and for the text having the maximum dispersion value ΔH_k^m. After that correlation coefficients are calculated for the massifs of pairs $\Delta H_k^s - \Delta H_k^p$ and $\Delta H_k^s - \Delta H_k^m$. The value of the larger correlation coefficient will point to the type of text.

As examples, the results of calculations for two text messages according to the algorithm described are now given.

For the first example, the Internet article by A. Kotlyarova (2015) is taken. Here is a fragment of text of the article: "The first self-service laundry was launched in dormitory building 8.1 on FEFU campus in early October. The driving force of creating an automated washing and drying services complex was the Department of development of FEFU campus…".

The text of the article was processed and brought down to calculation form. Here is the same text fragment after processing: "the first self-service laundry was launched in dormitory building eight dot one on fefu campus in early october the driving force of creating an automated washing and drying services complex was the department of development of fefu campus…". So, in calculations, the punctuation signs are not taken into account, nor is the letter case, and numerals are replaced with words.

Next, all calculations are performed according to the steps of the algorithm:

1. For each word of the source text, entropy is calculated according to formula (1). Next, the difference of entropies between two adjacent words is calculated according to formula (3).
2. According to expression (2), the criterion of estimation of meaning of the source information message ($\boldsymbol{M_s}$) is calculated as entropy dispersion of words coherence. The following result was obtained for this example: $\boldsymbol{M_s} = 0{,}778$ (bit/symbol)^2.
3. The source text is brought down to the probabilistic type by random relocation of words. Here is the same fragment of the article in the probabilistic form: "the driving force of an automated washing was october the department of in drying one creating early eight dot building of campus the first fefu in on fefu services and campus dormitory complex self-service development laundry was launched …".

   For the obtained probabilistic text, calculations according to item 1 and 2 are repeated and the value of information message meaning estimation criterion $\boldsymbol{M_p}$ is found. In the given example, it is примере $\boldsymbol{M_p} = 0{,}666$ (bit/symbol)^2.
4. The source text is brought down to the maximum value of entropy dispersion of words coherence. For this, words in sentences are combined in such a way as to obtain the maximum range of the interval between two adjacent entropies difference values. Here is the same fragment of the article brought down to the form with the maximum entropy dispersion value of words coherence:" in self-service was launched on in an automated creating and services was the dormitory one fefu of complex the department of fefu early the driving force building of washing dot campus drying

campus development laundry october first eight …". For the obtained text, calculations according to item 1 and 2 are repeated and the value of meaning estimation criterion with the maximum entropy dispersion of words coherence is found: $\boldsymbol{M_m}$ = 1,049 (bit/symbol)^2.

5. The meaning estimation criteria values for the source and probabilistic texts and for the one having the maximum text dispersion value are compared and analyzed. The result for this example is as follows: $\boldsymbol{M_p < M_s < M_m}$. The result obtained gives evidence about the source text probably containing meaning and reflecting the situation described in the paper in a relevant way.
6. In order to esti mate the text type, entropy coherence values of words are calculated for the source text ΔH_k^s, for the probabilistic one ΔH_k^p and for the text having the maximum dispersion value ΔH_k^m separately, for each sentence. For the example, this is the source text fragment broken down to sentences: "The first self-service laundry was launched in dormitory building eight dot one on fefu campus in early october. The driving force of creating an automated washing and drying services complex was the department of development of fefu campus…"

This is the probabilistic text fragment according to sentences: "early the first october in dormitory dot fefu campus eight building one self-service in on laundry was launched. and drying the department of campus of washing development was an automated services complex creating the driving force of fefu …".

Here is the same fragment of the text brought down to the form with the maximum entropy dispersion value according to sentences: "in self-service was launched in on the dormitory building one fefu of campus laundry early dot the first eight october. and an automated creating services fefu was complex of washing drying department the driving force campus of development …".

Next, correlation coefficients for arrays of pairs $\Delta H_k^s - \Delta H_k^p$ and $\Delta H_k^s - \Delta H_k^m$ are calculated. The value of the larger correlation coefficient will point to the type of text.

For this example, the following results were obtained:

- correlation coefficient for the pair of arrays $\Delta H_k^s - \Delta H_k^p$: R = 0,033;
- correlation coefficient for the pair of arrays $\Delta H_k^s - \Delta H_k^m$: R = 0,149.

Proceeding from the results obtained, it can be finally concluded that the text of this example most probably has got a meaning and belongs to the schizophasic type. I.e. the author tried to make the text of the article as informative as possible and succeeded in doing so. As the second example, the already mentioned text (a record of a talk to a patient) is taken from V.M. Bleicher's (1983) work. A fragment of this text is cited in its source form: "Where is Petya I was gone and

slept. And what do they want? and yesterday it was there is everything. Are you… everybody is here. Put off the lights. Where is wife? Got to go. Well, and how? Lost my spectacles…"

The fragment of text of this example looks as follows in its calculation form: "where is petya i was gone and slept and what do they want and yesterday it was there is everything are you everybody is here put off the lights where is wife got to go well and how lost my spectacles…".

After the calculations, the following results were obtained:

- criterion of estimation of meaning for the source text: $\boldsymbol{M_s}$ = 0,588 (bit/symbol)^2;
- criterion of estimation of meaning for the probabilistic text: $\boldsymbol{M_p}$ = 0,710 (bit/symbol)^2;
- criterion of estimation of meaning for the text having maximum entropy dispersion value of words coherence: $\boldsymbol{M_m}$ = 0,698 (bit/symbol)^2 ;
- correlation coefficient for the pair of arrays $\Delta H_k^s - \Delta H_k^p$: R = 0,331;
- correlation coefficient for the pair of arrays $\Delta H_k^s - \Delta H_k^m$: R = 0,376.

Proceeding from the obtained results, the conclusion is as follows: as in this example $\boldsymbol{M_p} > \boldsymbol{M_s} > \boldsymbol{M_m}$, then the source text most probably contains no meaning and belongs to schizophasic type i.e. its "author" tried to make the information message as informative as possible but did it unconsciously.

CONCLUSION

Thus, the main conclusion of this research can be brought down to the following. The less ordered the text of an information message from the viewpoint of probability distribution of words is, the higher the coherence dispersion is, and conversely. The regularity found allows using entropy dispersion of words coherence for quantitative estimation of meaning of human STA and of a text information message as criterion *M*, namely: the higher dispersion is, the more meaning there is, and vice versa. In case a human speech (text) corresponds to speech incoherence, estimation criterion *M* will tend to the minimum value and point to the lack of meaning. If it corresponds to schizophasia – the criterion will approach the maximum value and point to the lack of meaning too, or, more exactly, to the "excessive" meaning.

The following criteria are suggested for estimating the meaning of human STA:

- criterion of estimation of meaning for the source text information message $\boldsymbol{M_s}$;
- criterion of estimation of meaning for the probabilistic text information message $\boldsymbol{M_p}$;
- criterion of estimation of meaning for the text information message that has maximum entropy dispersion value of words coherence $\boldsymbol{M_m}$;

– correlation coefficient for the pair of arrays $\Delta H_k^s - \Delta H_k^p$;
– correlation coefficient for the pair of arrays $\Delta H_k^s - \Delta H_k^m$.

The paper is actually a theoretical scientific report submitted for further discussion. However, given the relevant elaboration, the results obtained can be used in practice in the areas of artificial intelligence, cognitive psychology and linguistics.

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