Computer Model of a "Sense of Humour".
I. General Algorithm

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Abstract
A computer model of "a sense of humour" is formulated. The humorous effect is treated as a specific malfunction in the processing of information, conditioned by the necessity of a quick deletion from consciousness of a false version. The biological function of a sense of humour consists in quickening the transmission of processed information into consciousness and in a more effective use of brain resources.

1. Introduction

In everyday life we use humour for amusement, as "a means of extracting pleasure from the psychical process" \(^{1}\) and we never ask ourselves why nature has provided us with the sense of humour. The bare fact that there exists a complex biological mechanism which causes specific muscular contractions (laughter) as a reaction to a definite combination of sound or visual images leads us to conclude that the sense of humour originated at early stages of the evolution\(^{2}\) when the possibility of obtaining pleasure should not have of appreciable importance. The present paper is an attempt to answer the question about the biological function of the sense of humour.

In the proposed scheme, the humorous effect is interpreted as a specific malfunction in the course of information processing conditioned by the necessity to delete some information transmitted to consciousness. The biological function of a sense of humour consists in quickening the transmission of processed information into consciousness and in a more effective use of brain resources. The proposed model accounts for different susceptibility of people to humour, the absence of a humorous effect from a hackneyed joke, the role of timing in telling jokes, etc. Some remarks on other emotions are also given. In the present

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2 According to Darwin \(^{2}\) antropoid monkeys possess a clearly distinct sense of humour.
work we formulate a general algorithm for a computer realization of a sense of humour; in the following paper [3] we discuss the possible realization of the algorithm in neural networks and the mechanism of laughter.

2. Humour from the psychological viewpoint

In psychology there exist several viewpoints on humour [4, 5, 6], the best – reasoned of which is the concept of incogruity advanced by the Scotch poet Beattie [7] in 1776. Its concrete treatments are different in different investigations; we accept the viewpoint close to the one advanced in the paper [5]: the humorous effect is a consequence of the ”commutation” of two mutually exclusive images (versions, estimates) in the human consciousness. In the simplest cases the commutation occurs on the level of meanings of a separate word (the play on words). For example in the joke

(1*) "My Uncle William has a new cedar chest”
"So! Last time I saw him he just had a wooden leg.”

the word ”chest” is at first realized in the meaning of ”box” but later it takes on a meaning of ”breast”. In other cases the commutation takes place on the level of more complex images:

(2*) The horse tradesman: ”If you mount this horse at 4 in the morning then at 7 in the morning you will be at Pittsburg.”
The customer: ”But what shall I do in Pittsburg at 7 in the morning?”

Here the words of the tradesman realized as ”the characteristic of horse speed” take on the interpretation ”giving directions how to reach Pittsburg by 7 in the morning”. Example

(3*) Is this a place where Duke of Wellington said his famous words?
Yes, it is the same place but he never said such words.

shows that the commutation may occur along the line of general estimate of a phrase: the second remark at first gives the impression of being ”natural” or ”logical” but later is perceived as ”absurd”.

The existence of two incompatible versions we were able to discover in all jokes; the explicit ”commutation” of versions takes place in approximately half the cases. The rest of the jokes are constructed according to the principle which can be called ”the ambiguity scheme”. In the example

(4*) Father (reprovingly): ”Do you know what happens to liars when they die?”

3 A detailed classification of the technical aspects of wit can be found in Freud’s book [1] where examples 2*, 3* are taken from. We give a simplified classification in accordance to the purposes of the present paper; in principle, it embraces all the cases considered by Freud.

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Johnny: "Yes, sir; they lie still."

the expression "lie still" may be interpreted as (1) "be motionless" or (2) "continue to tell lies". The specific feature of such cases is the practically equal possibility of the two versions: accordingly there is no definite succession of their appearance in the consciousness. It may be assumed that the commutation takes place in such cases also, but the order in which the versions appear is determined by random circumstances; repeated commutations are also possible.

The humorous effect is caused not only by "wit" discussed above, but also by the "comic" (exaggerated movements of a clown, grimaces, caricatures, parodies and so on). As the main characteristic of the comic, "the deviation from the norm" can be accepted; accordingly, the humorous effect is caused by the repeated commutations "the norm" — "not the norm".

The laughter from tickling can be connected with the attempt of the brain to localize the place of irritation of skin; the result of such localization is invariably rejected because the irritated place is changed unpredictably (that is the reason why the tickling should be done by another person).

3. Information processing

We begin the formulation of the computer model of "a sense of humour" by analysing information processing. Suppose that a succession of symbols $A_1, A_2, A_3, \ldots$ ("text") is introduced from the outside world to the brain: it can be a succession of words during visual or auditory perception. In the brain a set of images $\{B_n\}$ is associated with each symbol $A_n$: for example a set of meanings (a dictionary family) is put in correspondence to each word. The problem of information processing consists in choosing one image $B_{i_n}$ (which is implied in the given context) from the set $\{B_n\}$. The text will be considered as "understood" if the succession $B_{i_1}, B_{i_2}, B_{i_3}, \ldots$ (which visually can be imagined as the trajectory in the space of images — see Fig. 1) is put in correspondence to the succession $A_1, A_2, A_3, \ldots$. In principle, the algorithm of information processing consists in the following:

(1) all possible trajectories in the image space are constructed;

(2) a certain probability is ascribed to each trajectory on the basis of the information on the correlation of images stored in memory;

(3) the most probable trajectory is chosen.

Only step 2 is nontrivial here, i.e. the algorithm of ascribing the probability to a given trajectory. For example, such algorithm can be based on the binary correlations of images; in this case the set $p_{ij}$ should be stored in the memory where $p_{ij}$ is the probability of the event that in a meaningful text image $i$ will be followed by image $j$; the probability

Of course, not every "deviation from the norm" looks funny; but it should be taken into account that habitual, oft-repeated deviations are analogous to hackneyed jokes (see below) and the weak deviations are easily forced out by other emotions (see the following paper [3]).
Figure 1: The scheme of information processing: a set of images \( \{B_n\} \) is put in correspondence to each symbol \( A_n \) and one image \( B^n_{i_n} \) should be chosen from the set \( \{B_n\} \). The succession \( B^1_{i_1}, B^2_{i_2}, B^3_{i_3}, \ldots \) looks as a "trajectory" in the space of images.

of a trajectory \( i j k l \ldots \) is given by the product \( p_{ij}p_{jk}p_{kl} \ldots \). The probabilities \( p_{ij} \) can be obtained by the statistical treatment in the course of the "learning" process, during which a sufficiently long fragment of the "deciphered" text (i.e. recorded in images but not symbols) is introduced to the brain. A more complex algorithm can take into account the correlation between \( n \) images with \( n > 2 \): then the probabilities \( p_{i_1 \ldots i_{n-1} : i_n} \) of the succession of images \( i_1 \ldots i_{n-1} \) followed by image \( i_n \) should be stored in the memory. It is possible to base the algorithm on binary correlations but with the syntactical connections taken into account and so on. Algorithms of such type are being worked out in the investigations on machine translation \[8\]; the concrete form of the algorithm is not essential for the following.

The number of operations required for the realization of any algorithm of such type increases exponentially with the length of the text. So only fragments of the text containing no more than a certain number \( (N) \) of symbols can be immediately treated by such a method. How can longer texts be processed? The natural possibility is the following: during the processing of the first \( N \) symbols not one but several \( (M) \) of the most probable trajectories are remembered; then translation on one step made — the fragment from the second to the \( (N + 1) \)-th symbols is considered — and for each of the \( M \) conserved trajectories all possible continuations are constructed; then again \( M \) of the most probable

\[5\] The syntactic structure of a sentence has a form of a tree, so that each dependent word is related with its "host". The probability of a trajectory may be represented as a product of binary probabilities according to the structure of a syntactical "tree". The practice of machine translation \[8\] shows that the syntactic structure in most cases is clearly established by purely grammatical analysis (word order, adherence to a part of speech, harmonization of endings, etc.) and for the purpose of the present work may be taken as known.
Figure 2: The visual imagination of information processing: thin lines are trajectories conserved in operative memory, \( A \) is a front, \( B \) is the point where the branching is over, \( CD \) is a fragment of deciphered trajectory transmitted to consciousness.

trajectories are conserved and so on. It is reasonable to make the number \( M \) variable, so at each stage as many trajectories are remembered as the operative memory can hold. In the whole, the process looks as follows (Fig. 2): immediately after the front \( A \) the trajectory is branched heavily; at a certain point \( B \) the branching is over (the distance between \( A \) and \( B \) is restricted by the volume of operative memory provided for remembering the trajectories); the deciphered part of the trajectory \( DC \) with some delay \( AC \) is transmitted to the consciousness of the man and is realized by him as a thought (while the whole process takes place in the subconscious and is not perceived immediately).

4. The role of emotions in information processing

If numbers \( N \) and \( M \) are sufficiently large and the algorithm of calculating the probability of \( N \)-symbol trajectory is good enough, then the described scheme will operate successfully. However the probabilistic nature of the algorithm makes mistakes inevitable: so a mechanism is desirable for minimizing their consequences. Such mechanism exists and it consists in communicating to the consciousness some information about the course of the processing in the subconsciousness; the man perceives such information as emotions.
For example, such parameters of the process are essential as the probability $p_{\text{max}}$ of the trajectory transmitted to consciousness and the probability $p_{\text{comp}}$ of the most probable of the competing trajectories. The high values of $p_{\text{max}}$ and $p_{\text{max}}/p_{\text{comp}}$ signal a successful course of the process and are perceived as positive emotions (pleasure, confidence): the information obtained is considered as reliable. The low values of $p_{\text{max}}$ and $p_{\text{max}}/p_{\text{comp}}$ signal an unsatisfactory course of the process and are realized as negative emotions (annoyance, doubt): the corresponding information should not be taken too seriously. For very low values of $p_{\text{max}}$ no versions are transmitted to consciousness (complete incomprehension) and so on.

The possible relationship of emotions with the parameters of the process can be illustrated on the basis of the semi-empiric "emotion formula" proposed by Simonov [9]

$$\mathcal{E} = \mathcal{N}(I - I_0)$$

where $\mathcal{E}$ is the emotion strength (which is objectively measured by the pulse rate, the blood pressure etc.), $\mathcal{N}$ is a strength of some need, $I_0$ is the quantity of information demanded for the satisfaction of this need, $I$ is the quantity of information the subject has at his disposal (both informations are estimated subjectively). An emotion is positive ($\mathcal{E} > 0$) for $I > I_0$ and negative for $I < I_0$. We can suppose that in the course of information processing $\mathcal{N}$ is the need in information and the different parameters of the process determine $I$ and $I_0$ for different emotions. For example, $p_{\text{max}}$ can be used as $I$ for the emotion "pleasure of understanding — annoyance of incomprehension" (accordingly, $I_0$ is the typical value of $p_{\text{max}}$ ensuring the satisfactory course of the process). Analogously, $p_{\text{max}}/p_{\text{comp}}$ can be used as $I$ if $\mathcal{E}$ is the emotion "confidence – doubt" and so on.

These speculations lead us to conclude that the emotion expressing the humorous effect is also related to some specific situation in the processing of information.

5. The humorous effect

Let us discuss the nature of the delay of point $C$ with respect to front $A$ (Fig. 2). At first sight, point $C$ in a reasonably organized system should be always behind point $B$ or coincide with it: it is just the variant we surely choose writing the computer program. However, for a human as well as for any living creature such a variant is completely unsatisfactory. The matter is that the delay of point $C$ with respect to front $A$ results in the time interval $\tau_{AC}$ during which the information introduced to the brain does not appear in the consciousness (the man sees a bear but he is not aware of this). The prolongation of the interval $AC$ is obviously dangerous while the interval $AB$ can drag out for objective reasons (the man cannot decide what he sees: a bear or a bush shaped like a bear). Therefore, the interval $AC$ should have the upper bound $\tau_{\text{max}}$ on the time scale: if time delay $\tau_{AB}$ corresponding to the interval $AB$ is less than $\tau_{\text{max}}$ then point $C$ coincides with point $B$ (Fig.3,a); if $\tau_{AB} > \tau_{\text{max}}$, then $\tau_{AC} = \tau_{\text{max}}$ and point $C$ leaves behind point $B$ (Fig.3,b). In the latter case, the
Figure 3: The parameter $\tau_{\text{max}}$ is the upper bound of the time interval corresponding to delay of point $C$ with respect to front $A$; (a) $\tau_{AB} < \tau_{\text{max}}$, (b) $\tau_{AB} > \tau_{\text{max}}$.

most probable version $DE$ is transmitted to the consciousness while competing versions ($DE'$) are conserved in the operative memory (Fig.3,b) — their deletion is unreasonable because the brain has resources to continue the analysis. If in the course of the subsequent movement of front $A$ the trajectory $DE$ continues to have the maximum probability, then the competing trajectory $DE'$ will be deleted and the time will be saved as a result. If in the course of the movement of front $A$ the probability of $DE$ falls below the probability of $DE'$, then the brain will have a possibility to correct the mistake. In this case, however, the specific malfunction occurs: the fragment $BC$ transmitted to consciousness should be immediately deleted and replaced by the fragment of trajectory $BE'$. Psychologically this malfunction is perceived as interference of two incompatible versions: version $BC$ fixed by the long-term memory and the newly appeared version $BE'$. The described specific malfunction can be identified with ”a humorous effect”.

Indeed, the situation described is exactly reproduced in the course of the interpretation of jocular expressions. For example, in joke (1*) two incompatible versions arise in the subconsciousness during the analysis of the first remark: in the first of them ($DE$) the word ”chest” is treated as ”box” while in the second ($DE'$) it is treated as ”breast”. In the context of the given sentence version $DE$ (“box”) is more probable and is transmitted to consciousness. The appearance of the word ”leg” in the second remark makes version $DE$ less probable and increases the probability of version $DE'$ (“breast”): this gives rise to a humorous effect.

It is essential to emphasize that the existence of a humorous effect is not to any degree unavoidable: nature had a possibility to avoid it in one of the two manners: (1) by delaying the transmission of trajectory $DE$ to consciousness till trajectory $DE'$ is naturally discarded, or (2) by quickening the transmission of $DE$ by rejection $DE'$ simultaneously.
However, in the first case the time the information reaches consciousness is delayed and in the second case the brain resources are not completely used: so nature resolves this problem at the cost of psychological confusion.

In the process of evolution the optimal value of $\tau_{\text{max}}$ is achieved which ensures the compromise between the reliability of information and the speed of its obtaining (people with long $\tau_{\text{max}}$ will be eaten by a bear, while people with short $\tau_{\text{max}}$ will confuse every bush with a bear and will be incapable of getting food). For the optimal value of $\tau_{\text{max}}$ the inequality $\tau_{\text{AB}} < \tau_{\text{max}}$ is satisfied as a rule, and a humorous effect is rare enough in the natural conditions; but it can be easily produced by specially constructed witticisms and comics.

6. Some consequences

The model described offers a natural explanation for a number of well-known facts.

The failure of a hackneyed joke to produce a humorous effect is a consequence of the fact that a man knows of the existence of two incompatible versions beforehand and avoids the transmission of the clearly false version to consciousness (for example, knowing that in joke (1*) the "chest" turns out to be a "breast" he is not tempted to interpret it as "box").

The role of intonation in telling jokes is related mainly with temporal characteristics (pace, arrangement and duration of pauses, etc), which can be taken into account by incorporating an appropriate number of "spaces" in succession $A_n$. The quick pace of telling does not give time for the false version to be transmitted to consciousness and interval $BC$ (Fig. 3) turns out small or absent. The slow pace of telling increases the lengths of trajectories due to "spaces" and the competing trajectory $BE'$ (Fig. 3) is deleted from the operative memory; so the commutation of versions becomes impossible.\[6\]

Different susceptibility of people to humour\[7\] is connected (in case of equal intellectual level) with the differences in the delay $\tau_{\text{max}}$. People with large $\tau_{\text{max}}$ seldom laugh because point $C$ seldom outruns point $B$. Conversely, people with small $\tau_{\text{max}}$ are aware of a humorous effect even in cases that most people do not see as funny. Supposedly, $\tau_{\text{max}}$ is diminished by alcohol and this is a cause of the unmotivated gaiety. At fixed $\tau_{\text{max}}$ the susceptibility to humour correlates with the volume of the operative memory, which determines the average length of the interval $AB$ (Fig. 2).

Nervous laughter. If a mass of unpleasant impressions rushes at a man and there is danger of the overstrain of the nervous system then the organism forcibly deletes the

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\[6\] The dependence of humorous effect on duration of the pause in a certain place is well described in Mark Twain’s essay ”Public Speaking”.

\[7\] We have in mind the susceptibility to humour in principle, leaving aside the cases when individual peculiarities give rise to inadequate reaction to a concrete joke. The examples are incomprehension of a joke due to the absence in memory of a necessary image, peculiar view of the "norm" while perceiving the comic, the forcing out of laughter by secondary emotions (see \[3\]) and so on.
unpleasant information and replaces it by neutral: this gives rise to the reflectory laughter.

7. Conclusion

Freud [1] considers the pleasure obtained from laughter as the main cause of the existence of a sense of humour: a man discovers the possibility of extracting pleasure from the psychical process and begins subconsciously and then consciously to exploit it. Our viewpoint is the opposite: a sense of humour is biologically conditioned by the necessity to quicken the transmission of information to consciousness and of a more effective use of brain resources: so the pleasure obtained from laughter is not an essential factor (similarly, the two reflexes — sneezing and coughing — exist regardless of the pleasure afforded by the first and the displeasure caused by the second, because they are dictated by the biological necessity of cleaning out the respiratory system). Of course, if laughter afforded displeasure the social function of humour would change: the society would try to get rid of it by censorship, prosecution of witty people and so on.

Is it possible to create a computer program which will "laugh" in the same cases as a man? From our viewpoint it is quite possible if we restrict ourselves to the simplest types of jokes based on the commutation of meanings of separate words (example 1*); the corresponding program will not be much more complex than the average machine translation program [8]. Computer modelling of the more complex jokes involves the need to identify a complete set of images the average human brain contains and to establish the correct associative connections between these images. This would require many years of work of psychologists and programmers.

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