Modeling the Economic Efficiency of Advertising

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Abstract. The development of the economy and trade has led to the widespread use of advertising and the need for its constant improvement. There is a vast field of advertising theory. This paper proposes an information model of the functioning of advertising. We introduce ideas about useful and harmful (excess) information. The concept of user's thesaurus is also introduced. The effectiveness of advertising is determined by the mutual influence of useful and redundant information. Differential equations are formulated on this basis, the solution of which allows to establish the patterns of the influence of psychological characteristics of users and the mode of presentation of information on the effectiveness of advertising.

Keywords: advertising theory, information model, effectiveness of advertising.

1   Introduction: State of the Advertising Research

The advertising research has two directions. One of them consists in the staging of purposeful experiments and the creation of empirical formulas describing the identified experimental consistency. Another direction is the development of models and the mathematical description of these models. Then a comparison with experiment is carried out.

In [1-3] experiments were described to examine memory interference in an advertising context. The processes of remembering and forgetting advertising blocks in the human's brain are depending on the quality of blocks, clarity of advertisement.

At first, consumer memory for some advertising was inhibited as a result of subsequent exposure for other products in that manufacturer's product line and for competing products in the same product class. It happens preferably in the case of some kind of advertisement which is more attractive. Next, an experiment was performed which showed the analogous interference effects. In the third case it was obtained that the presence of advertising for competitive products changes the relationship between the repetition and consumer memory. Repetition had a positive effect only when there was little or no advertising for similar products [4]. This effect was also studied in the works [5, 6, 21, 24, 27, 29], in which the found experimental patterns are described using empirical formulas.

Mathematical models in this field have been developed for a long time [6-9, 20, 31-33]. They described empirical results in mathematical language. By this way, fundamental patterns are obtained. In [10-16, 39] a dynamic model of the company's sales dependence on advertising costs is constructed. It was shown that the advertising allows you to increase sales, but the dependence of increasing demand from increased advertising costs is not linear. Authors claimed that the advertising does not work instantly, since its inception, the information is accumulated in the minds of people with each meeting with advertising and reaches the peak after a certain time.

In our work, we use some representations of information theory for the implementation of an information approach with the aim of increasing the effectiveness of advertising.

Presentation of advertising is essentially a message of information to the consumer [17-19]. Therefore, the problem of increasing the effectiveness of advertising is reduced to considering the quality of the information presented, the mechanisms of its creation and presentation to the recipient, the psychological characteristics of perception of information by the recipient.

When creating advertising, along with clearly marked target information, extra information is usually added to "decorate" advertising [22, 26, 28]. This immediately affects the perception of useful target information. Further, in the course of the operation of advertising (in the course of its multiple presentations), the effect of "redundant information" arises.

This effect increases with time, prevents the perception of useful information and depends on the psychological characteristics of the recipient.

Information theory introduces the concept of information usefulness. Bongard [37] connects the usefulness of information with an increase in the probability of achieving the goal after receiving a message, in accordance with the formula:

$$V = log2 \, (P'/P) \qquad (1)$$

Here, P and P' are the probability of achieving the goal before and after receiving the information.

According to formula (1), the redundant information has zero value. However, in many cases, redundant information turns out to be useful and even necessary [38, 40-42].

In the case of the creation and operation of advertising excess information harms, reducing the effectiveness of advertising.

In the majority of works devoted to study the properties of advertising, it is believed that over time (an increase in the number of repeated presentations of advertising) there is an accumulation of information (I) perceived by the recipient (for example, [1-4]).

In fact, from the very beginning the advertising presents the necessary information for the recipient, and at subsequent presentations the new information is not added. Therefore, to talk about the accumulation of information for the recipient over the time of the functioning of advertising (increasing the number of presentations) is not entirely correct. That is why we introduce the concept of "enhancing of the information impact" which is not equivalent to the idea of the accumulation of information.

2　Description of the Information Approach in the Advertising Research

Usually the first perception of a new advertisement is surface, inaccurate and not fully understood [25, 30, 34-36]. Although the new information is not added, subsequent presentations of this ad lead to the fact that its content becomes more conscious, understandable, more deeply perceived.

For a quantitative description of the process of perception of advertising information, we found it convenient to identify the process of deeper "mastering" advertising with the accumulation of additional information and introduce a function of the information accumulation I = f(t). We assume that the number of advertisements presented (n) is proportional to time (t).

With a large number of presentations of advertising, its content is completely assimilated by the recipient and after some time begins to be perceived as redundant information. In this case, the accumulation of redundant information adversely affects the perception of useful information.

Thus, the perception of advertising depends on the mutual influence of useful and harmful (redundant) information. It is obvious that at the initial stages of the functioning of advertising, the influence of useful information prevails, but over time, as the accumulation of excess information, the latter dominates. The period of time after which the information begins to be primarily perceived as excessive depends on the psychological characteristics of the recipients and on their thesaurus.

But not only redundant information with a large n can adversely affect the perception of advertising. At the very beginning of the presentation of advertising (when it is created) it can contain harmful information that has a negative impact on the perception of advertising. Therefore, from the very beginning, the model should take into account the impact on the recipient of positive and negative information, as well as the interaction of these two types of information. We will consider positive information (contributing to the achievement of the goal of advertising) with a plus sign and negative information (reducing the effect of positive information) with a minus sign.

3　Formulation of Equations and Discussion of Results

Naming by $I_1(t)$ and $I_2(t)$ the functions of accumulation of positive and negative information, we write the kinetic equations:

$$\frac{dI_1}{dt} = T - \beta I_2 \tag{2}$$

$$\frac{dI_2}{dt} = -\beta' I_1 - T \tag{3}$$

In equations (2) and (3) T is a thesaurus of recipients; β is a coefficient of influence of the negative information on the positive one and β' is a coefficient of influence of the positive information on the negative one. It is presumed that $\beta, \beta' < 1$. From equations (2) and (3) we go to equation (4)

$$\frac{d^2 I_1}{dt^2} = -\beta \{ -\beta' I_1 - T \}. \tag{4}$$

The last equation has a solution:

$$I_1 = C_1 + C_2 e^{\beta\beta' t} - \frac{T}{\beta'} \tag{5}$$

where C_1 and C_2 are constants that are determined by initial conditions.

Using (4) one can write expression for I2:

$$I_2 = \frac{1}{\beta} \{ T - \beta\beta' C_2 e^{\beta\beta' t} \} \tag{6}$$

With initial conditions:

$$I_1(0) = I_2(0) = 0; \tag{7}$$

we obtain:

$$C_2 = \frac{T}{\beta\beta'} \; ; \quad C_1 = T \frac{\beta - 1}{\beta\beta'} \tag{8}$$

As a result, we get:

$$I_1 = \frac{T}{\beta\beta'} \{ e^{\beta\beta' t} - 1 \} \tag{9}$$

$$I_2 = \frac{T}{\beta} [1 - e^{\beta\beta' t}] \tag{10}$$

For large enough time periods one can write:

$$I_1 = \frac{T}{\beta\beta'} \{ [e^{\beta\beta' t}] \} \tag{9'}$$

$$I_2 = -\frac{T}{\beta} [e^{\beta\beta' t}] \tag{10'}$$

These results show that an accumulation of both kinds of information (I_1 and I_2) depends on their mutual influence. It is important that parameter values β and β' change in the process of advertising functioning. The competition of information I_1 and I_2 accumulation processes leads to the conclusion about two stages of advertising evolution. At the first stage, accumulation of I_1 information prevails and at the second stage accumulation of I_2 information prevails.

Considering solutions (9') and (10'), we take into account that these dependencies obtained are determined primarily by the exponent. We also take into account that at the first stage, β is small compared to β', and practically does not change. There is only a gradual increase in β'. This leads to the quality result illustrated in Fig. 1.

This situation persists at the first stage of the functioning of advertising. I_2 slightly decreases an accumulation of I_1. Expression (10') does not adequately describe the situation at the first stage, since the amount of redundant information is still small

The situation changes at the second stage of the functioning of advertising. Over time, the nature of the mutual influence of the two types of information changes. The

effect of I_2 on I_1 increases, and the influence of I_1 on I_2 drops. At the second stage of the functioning of advertising negative (redundant) information predominantly increases. This means that the effect of positive information will be reduced and although I_1 according to formula (9) continues to increase, but the "effective" value of I (I_1+I_2) decreases. In fact, I_1 turns into I_2, because the accumulation of redundant information in accordance with the model reduces the "quality" of positive information, therefore – its quantity. The noted patterns are qualitatively shown in Fig. 2.
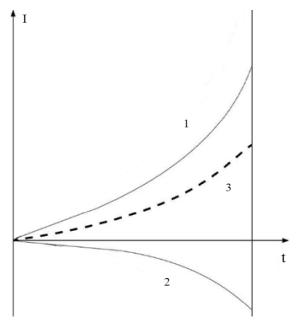

Fig. 1. Schematic illustration of I_1 information accumulation at the first stage of functioning of an advertisement. The curve 1 corresponds to I_1 accumulation and the curve 2 to I_2 accumulation. The curve 3 is an accumulation of a total positive information received by the recipient.

The perception of useful information throughout the operation of advertising (in fact, its effectiveness) is demonstrated in Fig. 3.

Based on the expressions (9) and (10) for the relative effectiveness (δ) of advertising can be written:

$$\delta = \frac{I_1}{I_1 + I_2} \tag{11}$$

$$I_1 + I_2 = T \frac{1-\beta'}{\beta\beta'}(e^{\beta\beta't} - 1) \tag{12}$$

$$\delta = \frac{T}{\beta\beta'} / \frac{T(1-\beta')}{\beta\beta'} \tag{13}$$
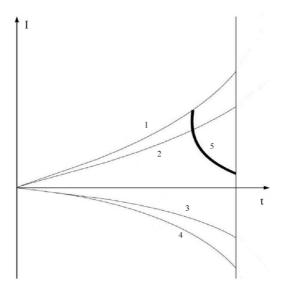
$$\delta = \frac{1}{1-\beta'} \tag{14}$$

Fig. 2. Schematic illustration of accumulation of a total information received by the recipient at the second stage. The first and the second curves correspond to the accumulation of positive information for two values parameters β' ($\beta'_1 > \beta'_2$), parameter β does not change. The third and the fourth curves correspond to accumulation of negative information for two values of parameter β ($\beta_3 < \beta_4$), β' does not change. The fifth curve corresponds to accumulation of total positive information received by the recipient.
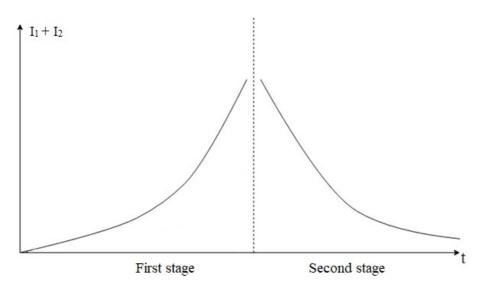

Fig. 3. Schematic illustration of total positive information received by the recipient during two stages of functioning of advertising.

Formula (14) in accordance with our model shows that relative effectiveness of advertising depends on the influence of the value of parameter β'. As we noted above, formula (9') describes the accumulation of positive information at the first stage of the advertising operation and formula (10') is applied to the second stage.

Due to the quality of advertisement the action of the advertising can be started in the different moments of time. This means that advertising can be disconnected for a while and then re-presented.

If the action of the ad starts at the moment t_1 the initial conditions will be formulated as:

$$I_1(t_l) = 0; \quad I_2(t_l) = 0 \tag{15}$$

In this case using expressions (5) and (6) we obtain:

$$C_1 + C_2 - \frac{T}{\beta'} = 0 \tag{16}$$

$$\frac{1}{\beta}\left\{ T - \beta\beta' C_2 e^{\beta\beta't} \right\} = 0 \tag{17}$$

$$T - \beta\beta' C_2 e^{\beta\beta't} = 0 \tag{18}$$

$$C_2 = \frac{T}{\beta\beta' e^{\beta\beta't_l}} \tag{19}$$

$$C_1 = T\left(\frac{1}{\beta'} - \frac{1}{\beta\beta' e^{\beta\beta't_l}}\right) \tag{20}$$

As a result, constants C_1 and C_2, in contrast to (8), are follows:

$$C_1 = T\left(\frac{1}{\beta'} - \frac{1}{\beta\beta' e^{\beta\beta't_l}}\right); \; C_2 = \frac{T}{\beta\beta' e^{\beta\beta't_l}} \tag{21}$$

Substituting these constants to (5) and (6) and using the formula (11) we obtain:

$$\delta = \frac{e^{\beta\beta't_l}}{e^{\beta\beta't_l} + \frac{T}{\beta}} \tag{22}$$

In this case the relative effectiveness of the advertisements significantly depends on the time when the advertisement does not act. We also see that in contrast to formula (14) in the last case the relative effectiveness depends on the thesaurus of recipients.

4   Conclusion

The effectiveness of advertising is determined by the perception of positive information by the recipient. Analysis of the information model of advertising leads to the conclusion of a two-stage process of functioning of advertising. This is due to the influence of redundant information on useful information that should be perceived by the recipient. Excess information appears as a result of multiple presentation of the

same advertising material. We claim that in the case of the advertising operation the redundant information is always harmful.

It is significant that the accumulation of both types of information occurs differently at different stages of the functioning of advertising. In the first stage, mainly positive information is accumulated. The accumulation of redundant (negative) information begins with a sufficiently large number of presentations of advertising (in the second stage). In this case, the accumulation of positive information continues, but it is suppressed by the predominant accumulation of negative information.

In Figure 1, the vertical line conventionally separates the two stages of the functioning of advertising. The position of this line depends on the psychological characteristics and the thesaurus of the recipients. Thus, when creating advertising, it is important to evaluate the period corresponding to the first stage of the functioning of an advertisement, for which a special psychological research is necessary. The effect of advertising depends not only on the quality of advertising, but also significantly on the thesaurus and psychological characteristics of the recipient.

The dependence shown in Fig. 1 is of the identical form as the experimental curves [3].

The obtained results show that for different initial conditions the advertisements act in different ways relatively their effectiveness (δ). It means that in the real conditions of advertisement operation its effectiveness can change not only in accordance with mentioned stages but under influence of other factors, such as turning off and subsequent turning on of the advertisement.

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