Ternary Codes in Psychology, Culture, and Art: Information Roots

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Abstract

A set of six models dealing both with spatial and temporal aspects of perception, forms an entity with tightly coordinated links. Though the models proceed from different concepts (optimization of the structure of the memory, minimal resource expense in information processing, etc.), they unanimously come to the preference for ternary codes, three-parametric systems, and three-object ones. This result is supported by numerous empirical data relating to different kinds of phenomena, primarily to fine arts.

Informational approach in cultural studies puts forth [1], and establishing *links* between its branches seems to be rather promising. The present paper is devoted to some of such links connecting properties of human *memory, information processing, threshold* of perception, and *works of art*.

'Spatial' Structures: Many-Sided Arguments in Favor of Triplicity

We shall consider the most *universal procedures* of information processing in order to come to some structural regularities inherent in works of art. Two preliminary notes should be made here. First, the models described in this Section deal with properties of objects (events), the information received is stored using certain *symbols* in the memory. This type of storing information is much more advantageous than storing it in the form of images ("gestalts"): it makes possible spending considerably less energy of the neuron net. Second, it is proposed that the primary data are *structured* in such a manner that it would provide maximal effectiveness of the information usage. That is why these symbols are grouped in certain clusters named "*parameters*." Let us turn to four partial models.

1). **Efficiency of Ternary Encoding**. In the simplest model, a certain 'resource' of W symbols is fixed. These symbols are divided into *equal groups* each consisting of x symbols (each group may be regarded as a scale of a certain parameter). Hence, the number of groups is W/x, and the given set of symbols permits to describe the number of different objects

$$y = (x)^{W/x}.$$

This value is maximal when $x=e=2.718\ldots$ (see example – Fig. 1). But the number of gradations should be *integer*. So, the 'economic' system consists either of ***ternary or binary parameters*** ($x=3$ or $x=2$).

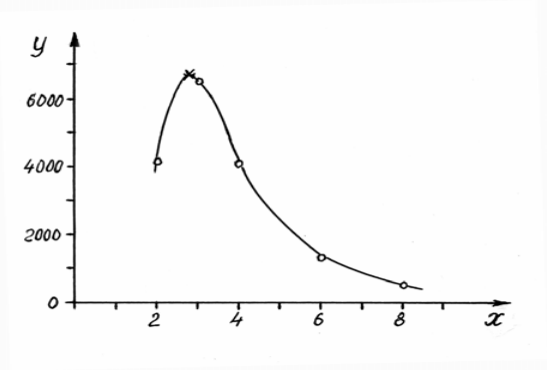

Figure 1: *The number of different objects* (y) *which can be described by a set of parameters possessing the given number of gradations* (x). *In this example the total number of gradations* (W) *is 24. Maximal value of the function responds to* $x=e=2.718\ldots$ *The preference for* $x=3$ *is clearly seen.*

2). **N-dimensional Vector Quantization**. In another model which is 'genuinely informational' [1, pp. 19-20], the '*response*' of a certain system (e.g., a man) is considered, this response being characterized by n independent components of a vector ('degrees of freedom'), each component again having x gradations of equal probabilities. The resource expenses are supposed to be proportional to the number of gradations: $r = a\,x$ (a being the constant). Let the total resource expense be restricted by the value $R = a\,x\,n$. The maximal *total information* I for the total resource expense R, was shown to be

$$I = (\ln xR) / a\,x.$$

This function is maximal when $x=e=2.718\ldots$, i.e., again we came to ***ternary or binary parameters***.

3). **Classification**. Sukhotin [2] considered the task of *economic 'non-motivated classification,'* when using *arbitrary numbers* of gradations for different scales. Think of a series of B objects described by a set of parameters, each consisting of several gradations. If we have $g(x)$ parameters with x gradations ('words'), then the number of possible classes is

$$y = \Pi\, x^{g(x)},$$

symbol Π designating the operation of multiplying over all x. Evidently, the number of such 'words'

$$W = \Sigma\, xg(x).$$

The informational optimization in such case means nothing but *economy of the total number of 'words'* under evident condition: sufficient description of the given number of objects: $y \geq B,\ W \rightarrow min.$

The solution of this system of equations comes to rather non-trivial result: only those parameters should be used which possess $x=2$ or $x=3$, i.e., only ***binary or ternary parameters***.

4). **Intensity-Independent Color Encoding**. Let us dwell upon the model of visual *perception of* objects' *color properties* in *changing illumination* – see, e.g., [1].

Let us have spectral photodetectors with *bell-like distribution of the response*: the peak value of the signal falls on a definite wavelength, whereas both at shorter wavelengths and longer ones, the signal is decreasing. How to determine the color of the object perceived, e.g., whether the given apple is red or green? To do this, we should compare the signal from the object, with the signal from the background (e.g., from the sun). But such a comparison may be ambiguous: each detector possesses two 'decreasing branches' of its spectral dependence, so that the percipient is not able to identify branches he/she is dealing with. Moreover, it is impossible to determine the color of the object, even resorting to the help of two types of detectors. Only using *three types* of detectors, it becomes possible to determine the color of the object. That is why it is namely this advantageous (and economic) solution that was used by the Nature in the process of the biological evolution, and exactly ***three-parametric*** system (possessing three types of cones) was realized in photoreceptors of human beings.

From 'spatial' arguments in favor of triplicity, let us turn to temporal aspect of perception.

Time and Order: Thresholds for Rapid Perception

We shall consider two universal situations taking place in case of *signal change* in perceived objects:

– identification of the very *fact of the change* in the signal;

– fixation of certain *regularities* in the changing signal.

5). **The Value of the Relative Threshold**. For the identification of the change, the *necessity of threshold* was deduced theoretically [1, pp. 116-122]. However, the *value of the threshold* is still unexplained, and especially its *constancy for different stimuli*. In fact, the value of the relative threshold of perception is the same for different kinds of stimuli: intensity of light, loudness of sound, etc.; it is close to 12-15%. Meanwhile, proceeding from the model of ***three parameters***, we can explain this riddle, as well as the *capacity of the first step of human memory* ("Magic Number 7±2"):

– as far as *high speed* of functioning is the main criterion of the effectiveness for the first step of memory, the evolution chose the simplest and the most reliable way to form this step: to use three informational channels, each responding to transmission of the binary signal (e.g., 0 or 1); as a result, a 3-channel operative memory device is formed, with the *total amount* of cells $V = 2^3 = 8$;

– the relative *threshold of perception* is simply a result of the functioning of such 8-cell memory device: e.g., when all 8 units are occupied, to empty one of them means to lessen the stimulus intensity to 1/8 of its magnitude, i.e., to 12.5%. So, the threshold $S \approx 1/V$.

6). **Detection of Periodicity**. Finally, when speaking of certain *regularities* in changing signal, we should focus on the most universal task in this field: fixation of the *repetition of signals*. Hence, the main "personages" of our consideration will be the *probabilities* of certain events. Here the heart of the matter is the search for *regularities* within the 'world of events': statistical *links* which are capable of generating *positive emotions*. Think of a '*hedonic subject*' in the following *typical situation*.

There exists a certain *'lattice' of events* which are more or less *regular*. Example of such regular lattice is the sequence of dawns: they come every day, with 24-hour periodicity, so dawns are the 'knots' of this lattice. On the basis of this 'primary' periodicity, another kind of cycles (i.e., another lattice, named 'secondary') may occur, for instance, Sundays: they form 7-day periodicity. These regular events form the *secondary lattice*, maybe rather important for the *personality*. Let the probability to meet the given secondary event in a certain position be p_k; e.g., $p_k = .2$, if a person plays roulette every day, and one day he wins a large sum, then after four 'waste' days, he again wins, and so on. Hence, sooner or later he concludes that these happy events are cyclic, with the period of 5 knots. But when exactly he can realize this periodicity? – The problem seems to be very important, especially for *works of art*: here the regularities found should generate *positive emotions*.

Evidently, an event is considered to be regular when the person sees: the *probability of accidental occurrence* of the secondary event *at this knot* is negligible, i.e., it is less than the relative *threshold of perception* S. Hence, the probability to meet the event in question, n times in 'due' positions

$$p(n) = (p_k)^n \le S.$$

But we know that $S \approx .15$, and the value n should be *integer*. So, for the most widespread situation when $p_k = .5$, we have $n \ge 3$. It is namely the moment of the *first discovery* of the regularity that is the most striking for the person, resulting in *positive emotion*. This emotion determines the perception of the entire sequence of the events. Naturally, this moment depends on p_k; it was shown: in order the second appearance of the event to be the indicator of a periodicity, p_k should be less than $\sqrt{S} \approx .39$. That is why in *poetry* we never see *devices* which are met regularly and possess the frequency of occurrence exceeding .38. For instance, *associative 'gluing' of stanzas* is usually met in 30% of inter-stanza borders; almost the same frequency was observed in *prosaic works* [3].

Nevertheless, the most widespread situation responds to the above version: $p_k = .5$, i.e., the case of a binary choice – the given secondary event should either be met at this place, or not, with equal probabilities of both versions. Such case is typical at least for the first repetition of the secondary event, i.e., when $n=2$, because of unknown a-priori probability of the event considered. And at the second repetition ($n=3$) the sequence of events becomes perceived as evidently quite regular: $p(n)=.125<S$. Hence, we see the preference for ***three events*** which is 'dictated' by the perception.

From Psychological Regularities – to Artistic and Cultural Ones

So, three-gradation scales, three-parametrical systems, and three-event situations are preferable for perception. However, the triplicity – should it be met in all situations? – Of course, not! Considering the roots of this phenomenon, we ignored the "*content*" of objects perceived. For instance, if the events are sad, the emotion would be negative, and the triplicity occurs *disadvantageous*.

Situations giving *maximal chances* to the triplicity, are typical for the sphere of *art*, where the *disinterested perception* plays an important role. One of appropriate empirical findings relates to *colors* used by painting [4]. The following regularity was deduced in the framework of the information approach: in each national culture, a set of *three 'main colors'* (the so-called 'national color triad') should dominate the system of painting. Spectral characteristics of these "main colors" are determined by geographical specificity of appropriate region (primarily by the character of the sunlight typical for this

region). Thus, for French and Italian painting such a triad consists of yellow, orange, and dark blue colors, in Spain these three colors are white, red, and black, and in Russia white, red, and green. These theoretical predictions were corroborated by empirical investigations which dealt with paintings of the 15th-20th centuries: French, Italian, Spanish, and Russian school, represented by 311, 109, 106, and 296 works, respectively. In each work its '*main color elements*' (constituting its color structure) were identified by experts. Some of the results obtained are presented in Table 1.

The *preference for triads* (see last column to the right) is evident; the values responding to 95%-level of tolerance, are marked by asterisks. In addition, statistically significant difference was found between usage of each 'triadic color' in different national schools: only French and Italian paintings are almost identical in this relation, but they both differ from Spanish and Russian painting; as well the last ones differ from each other and French-Italian school. Apropos, such behavior confirms the existing views on French and Spanish cultures as 'rigid' ones, while Italian and Russian cultures seem to be 'softer,' easily influenced by foreign cultures. Among other numerous evidences of the preferred triplicity (see also [5]), we find three main personages in fairy tales and prosaic works, ternary structures in religion, language [1], and other fields.

Table 1. *Percentage of paintings with the following 'main colors' and 'due' national color triads*

Country	***Red***	***Orange***	***Yellow***	***Green***	***Blue***	***Dark blue***	***Violet***	***White***	***Black***	***National triads***
France	37	51	55	30	19	25	33	29	20	***42****
Italy	46	42	63	17	39	23	22	21	26	***25***
Spain	55	5	58	4	14	19	25	55	59	***52****
Russia	50	14	47	40	11	35	34	44	24	***29***

But the realm of the phenomenon considered is not limited by the sphere of arts: due to rather universal (non-specific) character of this phenomenon, it is capable of penetrating many other spheres, based on *unconscious processes*. For instance, the *three-dimensional semantic space* which is inherent in most perceptual processes (namely such space is usually fixed in psychological experiments using 'semantic differential techniques'), is one of the consequences of the triplicity. Moreover, the *three-dimensionality of* our *perceptual space* can be also ascribed to the same principle: we wish to receive *positive emotions* when perceiving various objects and/or events; hence, it is desirable to plunge them into the three-dimensional space. Both 'spatial' and 'temporal' motives are "pushing" us to such worldview. In general, our positive emotions caused by the processes of identification of links in the world of objects and events, are tightly connected with our very *survival*, and the triplicity – observed both in *everyday life and works of art* – is one of our means in unconscious *search for regularities*.

References

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