incomplete. On the other hand, insofar as the concept of meaning is the last refuge of gods in the explanation of human behavior, these models may allow us to replace this concept with more materialistic hypotheses about human behavior.

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Comment by Jacobo Grinberg-Zylberbaum

Relationship between information and meaning

The understanding of the relationship between information and meaning is of paramount importance to the biological sciences. Both terms seem to reflect two qualitatively different realms of reality and simultaneously are in such a way derivative one from the other that their strict analysis is filled with difficulties.

I think that information has meaning when its content fits into a system of thought, a theory about reality or a matrix of feelings in which the meaningful information clarifies or explains some process. Meaning is different from information (in the above mentioned instances) as an algorithm is different from a single bit of data. In other words, information that has acquired meaning behaves as a 'key' of understanding.

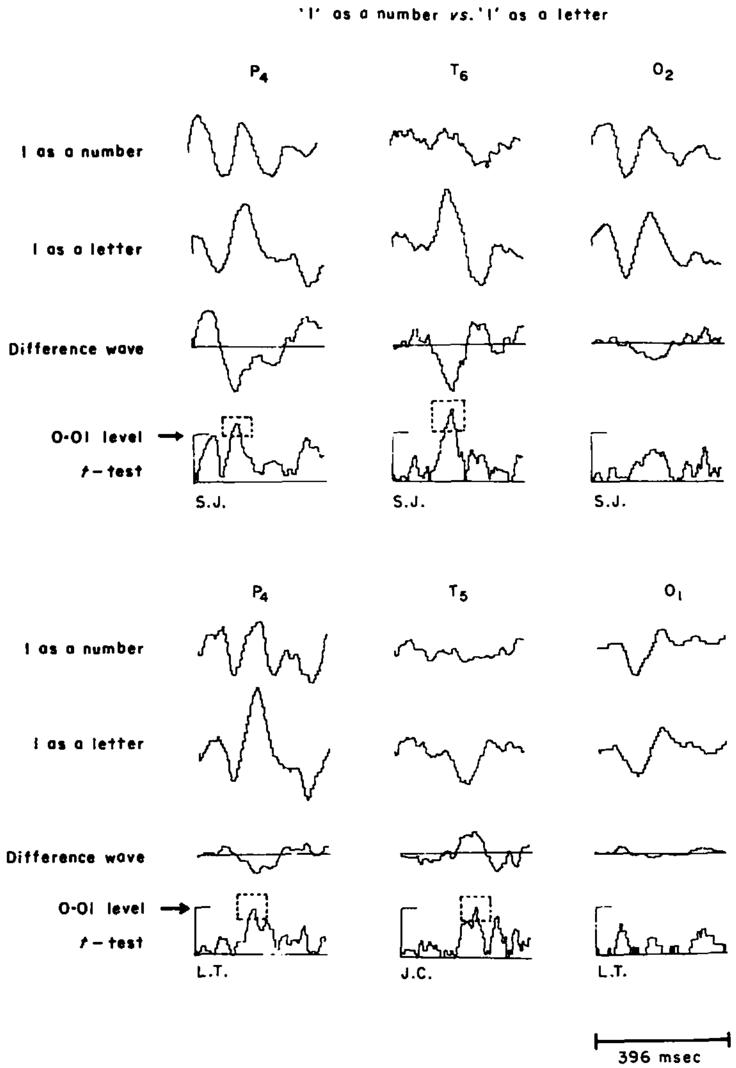

Fig. 1. This figure depicts the waveform of evoked potentials (E.P.) obtained by presenting a vertical line in a context of numbers (first and fifth lines) and of letters (second and sixth lines). Only parietal and temporal deviations showed differences in the E.P. morphologies (see t-test)

If some apparently disperse information is given to a subject who is incapable of finding conceptual bridges that connect one piece of information with others, he feels that the information has no meaning. If however the observer is able to connect one piece of data with the others, he has the feeling that each bit of information has a meaning and all the pieces form a meaningful matrix.

In this sense, some information has meaning when its content can be reduced or rerresented in an algorithm (because an algorithm is always a reduced formula that interconnects pieces of data), and is meaningless when it cannot be algorithmically represented.

If the above mentioned concepts apply to the brain, it is necessary to find if neuronal algorithms exist and if their appearance is correlative with the process that transforms information into meaning.

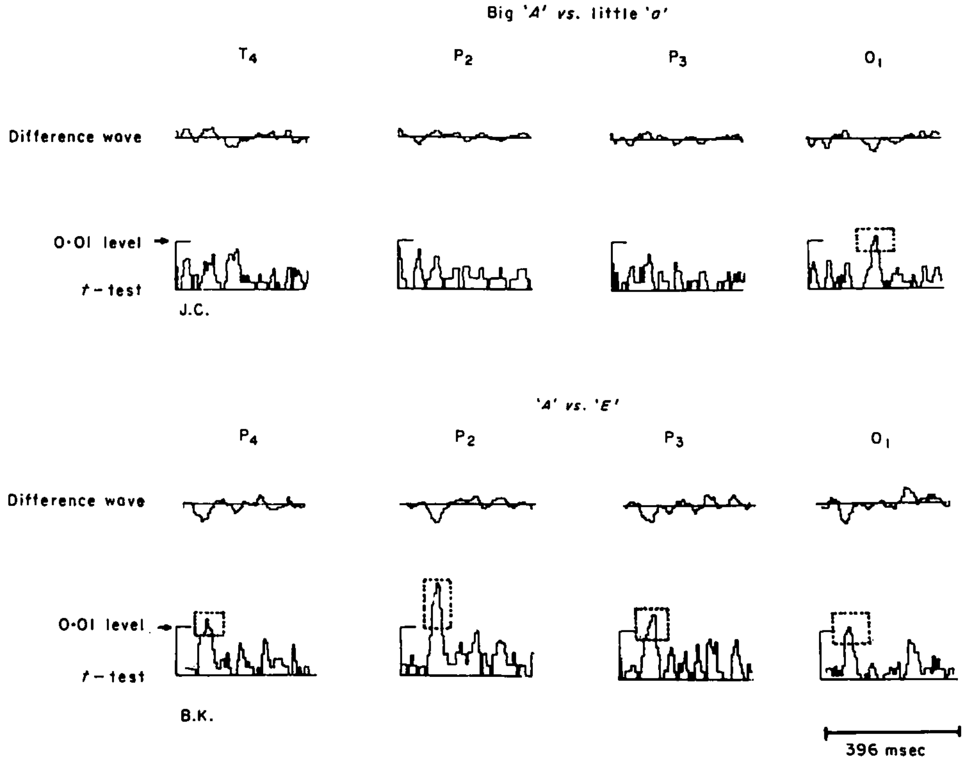

Fig. 2. This figure shows the difference wave and t-test statistics of a comparison between E.P. stimulated by a big A vs. *a little a (top) and an A* vs. *an E (bottom). Differences were found only in occipital sites when a big A* vs. *a little a were presented and in occipital and parietal when an A* vs. *an E were compared*

From a purely anatomical point of view it is possible to describe neuronal circuits capable of integrating information into what can be considered neuronal algorithms. The retina is a good example. In the human eye, the retina transforms about 136 million discrete points of activation (at the receptor's level) into just one million output lines of activity at the optic nerve axon's.

Everything at the level of the retinal image is meaningful in the sense that no single portion of it is separated from and independent of the others. The problem for the retinal circuits is to reduce a 136 million interrelated but discrete points of activation into one million interrelated and also discrete output lines not loosing but (on the contrary) amplifying the matrix of relationships of the retinal projection. In other words, the optic nerve has to build a neuronal algorithm of the retinal 'image' using the natural structure of the retinal circuits as a tool. Of course, at the level of the retina, the 'image' that exists is a pure energetic matrix without the form and features that result later as an outcome of the creation of the perceptual image. Evolution has built a retina that in its structure resembles or at least incorporates the logical structure of the universe in it so that its algorithmic labor of decodification does not distort the natural logic of the external world. This retinal labor of reduction of details and increase in algorithmic power is the core of the process that transforms information into meaning.

Now, it is not enough for information to be algorithmically boasted for it to acquire meaning. The neuronal algorithm transmitted in each optic nerve has to be recognized and decodified as an algorithm of an image in order to acquire meaning. Whatever process ocurrs in order to fulfill the above stated manouver remains a mystery.

Roy John and myself (1981) made an attempt to find out some physiological correlates of this process using evoked potentials (E.P.). We recorded the E.P. waveforms elicited by the same vertical line when it was interpreted as the number *one* and when it was interpreted as the letter *I*. We found that in occipital derivations both E.P. did not differ but in parietal and temporal ones they did (see Fig. 1). On the contrary, when a big letter *A* and a small letter *a* were presented, only the occipital E.P. differed while the parietal and temporal did not (see top of Fig. 2), and there was a difference in all E.P. recorded from occipital and parietal derivations when a big *A* and a big *E* were presented (see bottom of Fig. 2) and compared.

The above experimental results indicate that in temporal and parietal structures, the process by which a neuronal algorithm is recognized takes place thus giving rise to meaning.

Now, of course, the problem of how this process of recognition takes place in the brain and how the actual vivid experience of meaning is extracted from it remains unanswered.

I have postulated that as a result of the three-dimensional activation of populations of neurons in the brain, an energetic field is produced. This 'neuronal field' must vary its morphology correlatively with changes in the flow of information in the three-dimensional brain neuronal circuits, thus representing the functional dynamic of these circuits at an energetic field level. Furthermore, I have postulated that the neuronal field establishes an interaction with some level of the energetic structure of space and that experience is related to this interaction (Grinberg-Zylberbaum, 1981, 1982, 1983).

Further experiments must be done in order to test these ideas and to understand how the experience of meaning is actually being felt.

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Comment by Lester Ingber

I agree with the major thrust of Ferdanzo's complaint that I and the other cited authors do not really come close to solving pressing worldly problems that require a 'more imprecise metaphorical sense of information as meaning'. But that is the extent of my agreement, and he has unfairly and uncritically made claims about the intentions of these authors:

Although guilty as charged in using the term 'information' in a strict sense in my article in this journal (the precise biology, physics and mathematics of which is in *Physica* **50**, 83–107 and *Phys. Rev. A*, in press), ironically, my article immediately following in that same issue deals with the importance of 'information' probably best relegated to be considered in the metaphoric sense. Furthermore, I believe that the other authors cited also have the education and intelligence to appreciate that their *critical* (certainly not 'uncritical' as charged) definitions of 'information', having to do with explicit physical structures and