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Cognitive Struggle with Sensory Chaos: Semiotics of Olfaction and Hearing

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Quodcunque ostendis mihi sic, incredulus odi.

Horat

They haven't got no noses

The fallen sons of Eve;

Even the smell of roses

Is not what they supposes;

But more than mind discloses

And more than men believe.

G.K. Chesterton

'The Song of Quoodle'

Our perception of any physical input depends on the characteristics of the sensory systems. These are our windows to the world as well as the doors through which the world enters our mind. But even after reaching the receptors sensory information does not loose its diffuse and fuzzy nature: it is nothing but a flow of chemical, acoustic, mechanical or light waves of some kind that still have to be organized and - most importantly - categorized in a manner consistent with the constraints of a certain kind of living species. Every living being on this planet has its own *Umvelt* adapted to its own specific needs (Uexküll,1928).

Immanuel Kant divides body sensations into *sensus vagus* (warmth or cold, alarm, hope, shrill or trembling caused by reading fairy-tales to children) vs. *sensus fixus* (*Organsinne*). There are five of such *Organsinne*: three of them are rather objective than subjective, i.e. serve to explore and understand the external object; the other two are more subjective, i.e. serve to get pleasure, not understanding. That is why there is much more consensus on *sensus vagus* than on *sensus fixus* both in empirical perception and nomination. The senses composing the first group are, according to Kant, *tactus, visus* and *auditus;* the second group is - *gustus* and *olfactus.* Vision is described by Kant as the most 'noble' of all, including the other 'mechanical' - tactile and auditory, while taste and olfaction – the chemical senses - as 'the lowest'. The most 'unnoble' according to Kant is olfaction. However, these chemical sensations (or *pica* as Kant calls it) help awaken our attention and cope with monotonous and dull thinking... Individuals are described as *sensibilitas sthenica* vs. *sensibilitas asthenica*. (Kant, 1800). I would add that taste and vision provide greater freedom than sound and olfaction, which are much more aggressive: an individual is involved in joint perception having no chance to escape when in the relevant space.

Similar to this, in his Existential Semiotics Tarasti discusses *strong* and *weak* (*inner*) signs. He stresses that *weak signs* can energetically form ones behavior and be existentially vital to the formation of ones specific *Umwelt* (2000). Composition of such a semiosphere inhabited by *Kant, trees, stones, and horses* (Eco, 1999) depends on how well the senses function, and still more important - how the brain works.

To compose a specific semiosphere and live in it higher animals and humans need not only such doors and windows, but a cortex. The brain uses...'chaotic dynamics to create and test hypotheses about the environment, which are evaluated by sense data, which are then discarded. All that brains can know is constructed within the forebrain through landscapes of chaotic attractors created by the neurodynamics of intentionality' (Freeman, 2001).

Language appears to be the best vehicle to oppose the sensory chaos that we meet every millisecond: it labels cortical representations of input information, and normalizes subjective experiences of individuals and thus subserves more or less comparably both communication and evaluation of the world. This means that language, being a cultural phenomenon though based on genetically developed algorithms, relates natural objects to neurophysiological events via conventional semiotic mechanisms. Our perception could be described in vague terms of objectiveness only because we have an agreement in naming, i.e.'boxes' in which to pack the sensations. The elegance and quality as well as the size of the 'boxes' vary from language to language and from individual to individual. There are accidents of perception like false sensations (illusions or even hallucinations), but the brain and the language it uses to label them cope with it, irrespective of their relevance. We are supposed to connect *words* and *things* or *events*. In some cases we appear to be more successful (with colors and lines), in the others - much less. Synaesthetic perception is one of the puzzles that we face. Artistic personalities and scientists (such as Aristotle, Newton, Goethe, Helmholtz, Skrjabin) were known to have this ability and to explore it (Cytowic,1989; Zellner, Kautz, 1990; Caiovano,1994; Emrich, 2002) Kandinsky (1947) wrote that some colors can be described similar to tactile sensations - as rough or prickly, smooth or velvety. Very impressive descriptions come from Luria's patient - a mnemonist with a synaestesia (1968). Humans become more and more 'egocentric' and hyper-semiotic with colors: we meet such color descriptors as jet-black and cosmic-blue (which is not blue and attached only to a certain car, i.e. having no group to be inserted into) that are socially and contextually based.. We have to label such difficult sensory concepts as movement, intensity, instance, size, etc. We do it with a specific 'language', a kind of a mentalese. Jackendoff (2002) introduces a concept of *f-mind,* which is understood as an ability to code by natural human language certain combinations in a neuronal net in relevant brain regions, thus bridging the gap between computing and therefore the self-sufficient brain and the external world (cf. Freeman, 2001; Fodor, 2001; Chomsky, 2002; Loritz 2002). The brain needs language for self-description. In this context it is reminiscent of Deacon's (1997) paradoxical issue: language is a parasite that occupies the brain, and we see their co-evolution, with language playing the major role. Then, are there basic things that we share with other species? Do we categorise at least some stimuli in a similar way, and does it give us a chance for trans-species communication?

Auditus

Numerous lines of research on vocal communication in different species agree that there is quite a lot of such communication. Many researchers have demonstrated that close species are more successful in understanding each others' codes, and humans easily get relevant information from the acoustic signals of monkeys and apes. All biological species are sensitive to formant frequencies, all identify individual voice characteristics, all understand emotional features encoded acoustically using underlying limbic mechanisms. All can code movement of sound and its trajectory (back or forth, left or right), and can form subjective acoustic space. Cerebral mechanisms subsurving such functions have been demonstrated in humans:hemispheric specialization was shown not only for higher but also for some lower-level sensory functions. As an example, we demonstrated that the left hemisphere (LH) quickly and accurately recognizes amplitude changes in high frequency (3kHz) acoustic signals with high rhythms of tonal bursts (60 Hz), while the right hemisphere (RH) is more successful with low frequency carrier (0.25 kHz) and low rhythms (20 Hz) (Vartanian, Chernigovskaya, 1992).

The data obtained by us (Gershuni et al. 1976) show that communication signals of monkeys Cebus Capucinus are appreciated by humans (Table) and, moreover, could even be transcribed by phoneticians (emotional characteristics were determined from the tape recording of the signals by both naive and experienced listeners including phoneticians - all were unaware of the real source of the recording and were informed that the stimuli were *complex sounds*). The reason for such successful cross-species processing lies among others on several issues: all the signals of monkeys and apes are well grouped according to their acoustic characteristics; the frequency band is between 100 Hz and 6 or 8 kHz - which is adequate for sensitive human hearing; vocal peripheral mechanisms are similar in both species; cerebral mechanisms of sound processing are also similar. Amazing was the similarity of emotional categorization of the signals by listeners on the one hand and behavioral role of those in primate communication on the other.

It is evident that all species develop and explore semiotic systems of their own, and in this sense there is no gap between humans and other inhabitants of our planet. However, humans have elaborated a much more complex and conventional semiosphere, subserved primarily by natural language, which gives us the possibility to talk about the past and future and about objects having no external referents, while other animals use minimal amounts of signs subserving current states and situations. Of special interest in this respect in a paper by Hauser, Chomsky and Fitch (2002): the position is becoming much more mild: no rigid distinctions between animal communication and human language anymore, and the scheme is much more flexible and rich.

Olfactus

Sensory systems do not share every functional feature. The ear is an analytical organ, distinguishing components, composing a complex sound, while the eye is synthetic and almost incapable of such analysis. Olfaction also is holistic (at least in humans) and processes the world in a Gestalt fashion. An odor acquires meaning through learned associations,; emotional conditioning may be 'hard-wired' through the projections of olfactory pathways to the limbic system, so that emotional responses are source oriented. This is depicted in odor nominations: words are mainly names of such sources (lemon, garlic, mint,etc.).

Chemo-communication provides orientation and adaptation of the whole biosphere 'horizontally' and 'vertically', stabilizing homeostasis from intercellular to interorganismic and even interpopulational levels. No wonder that 'chemical language' is so delicately ellaborated in nature...

Olfaction provides information about chemicals suspended in the air which excite receptors located at the top of our nasal cavity which in turn connect with the olfactory nerve - very close to the peripheral apparatus. Recent data show that the amazing ability of animals (much worse in humans) to discriminate an individual olfactory stimulus in a mixture of unfamiliar stimuli might be caused by a large number of independent channels, with elements of binary coding allowing a rough approximation of the level of each channel arousal, and even the possibility of separate transfers of information about stimulus quality and the intensity (Minor, Krutova 2001). Humans have 10^8 olfactory cells covering a large area - 25 cm^2 (to compare: the analogous area in dogs is $7m^2$). Chemical information goes directly to the brain (toxic substances that we inhale are accumulated not only in the liver, but in the brain too).

A new branch of knowledge - semiochemistry - has emerged, as olfaction is very important for behavior not only in the majority of animals, but in humans also. Fragrance is a part of a social Gestalt; odor and context together can become necessary elements of a very complex picture, governing individual and social interactions and preferences (Kirk-Smith, Booth, 1987; Schaal et al., 1998;). Smell often provides the sensory basis whereby members of a species and individuals within a species recognize each other. Pheromones regulate certain kinds of behavior in a group. There are gender and age differences in processing odours: females and younger individuals do it better than males and the elderly. It is known that sexually mature women are more sensitive to the smell of certain musklike substances than are men and very young girls, and this sensitivity depends on the level of estrogen (female hormone).

The visual (especially color) semiosphere is probably the most delicately elaborated by the majority of human languages, while the olfactory is the least verbalized of all sensory modalities, probably due to it's subconscious nature and cultural prohibitions. Such information is complex, fuzzy, and there is not a vast vocabulary for odors in the mental lexicon. In fact, it borrows labels from other domains. Other modalities, such as tactile, auditory, and gustatory occupy more intermediate positions on this scale.

Color is a spatial sign, sound is a temporal, odor and taste are probably both. Synaesthetic perception is to be expected, the iconicity of which is evident. The iconicity of olfaction can be described as a kind of cognitive synaesthesia. It involves associations with past images, and reveals episodes of personal experiences, often thought to be lost long ago.

Several classification schemes exist for describing odors by reference to 'primary sensations' - like fragrant, spicy, putrid, etc (e.g. Amore, 1963; Harpar et al., 1986; Dubois, 2000). Olfactory memory, however, has some very important distinguishing characteristics which may suggest its uniqueness in cognition (Engen, 1991; Zucco, 2003). One of the most important peculiarities of odour recognition memory is that it is only slightly influenced by the length of retention intervals relative to that for verbal and visual stimuli. This effect was observed for short intervals (a few seconds and minutes), as well as for much longer retention periods up to a year. Odors are poorly remembered initially and well retained over time. One should also consider the fact that when modelling olfactory perception our devices do it by analysis, and it is organized by time, while our nose does it in an opposite fashion – integration. Odor memory seems to be unaffected by the familiarity of the substances used. Categorisation of olfactory stimuli is also not an easy task: odors might be grouped by different multimodal principals such as personal memories and broader Gestalts, emotional backgrounds and current states. Dubois argues (2000) that in audition and olfaction the gap between linguistic and cognitive categories is much larger than in the visual domain. The groups will be different in different situations and in different testing sessions. They are personal, emotional, and very unstable. Odor labeling and verbal rehearsal have no effect on subsequent recognition memory. Danthiir et al., (2001), have shown that olfactory memory ability is independent from other higher-order abilities. It might be possible it is in some sense a separate module.

Zucco's main hypothesis relies on the assumption that odors do not give rise to a conscious representation and could be stored in memory at a subconscious level. Conscious access to the olfactory trace is not possible except for acquisition and intentional retrieval. Storage and access to olfactory stimuli in memory, then, should not imply an effort but be automatic.

Odors conquer the whole mind, evoking situations and emotions associated with similar olfactory pictures. In our interviews with the blind it was clearly evident that olfaction plays very important role in their behavior and cognition, compensating for visual deficit. Blind musicians touring with an orchestra told me that they had vivid olfactory portraits of cities and towns, to say nothing of such portraits of other people, stores, transport and streets. Their olfactory semiosphere is much richer than that of an average person.

Brain & Nose

Odours can remind us of very distant memories. Such memories are often characterised by unusually strong emotive connotations. This ability is due to the direct anatomical links between the primary olfactory cortex (Fig.1) and the structures in the limbic system as shown by functional brain imaging of olfactory perception (Economides, 1986; Freeman, 2001). PET imaging of synaesthetic processing also shows unusual neural connectivity (Paulesu et al., 1995) .

Human thinking is heterogeneous: we see it in different cultures, modes of education and as cerebral hemispheric organization of higher cortical functions. It is widely accepted that the thinking provided by the left hemisphere (LH) is formal, and analytic, while right hemisphere (RH) thinking is metaphoric, Gestalt-like, and mosaic. It has been shown that the RH is more efficient when isolating relevant features from the mosaics of all features, including those which are irrelevant. It can operate with several types of uncertainties: inexactness, incompleteness, probabilities, fuzziness, observation errors, etc. It also has been shown by many authors that the RH governs emotional production and perception and some types of prosodic cues (Chernigovskaya, 1994, 1996, 1999; Chernigovskaya et al., 1995). Such a strategy was likely the one that allowed the successful understanding of monkeys' signals in our experiments discussed above. It demonstrates vividly that the evolutionary older RH supports cross-species contacts and helps adaptation in nature in general (Chernigovskaya, Arshavsky, 1994, 2003).

In apparent contrast to numerous lines of research on other sensory modalities the role of hemispheric functions in the chemoreception, evaluation and verbalization of odors is not well known. However, RH has been shown to be involved in processing odors. This was observed in brain injured patients as well as in normal subjects (Toller, 1980; Abraham, Mathai, 1983; Zucco, Tressoldi, 1989, Zatorre et al., 1992)

In our research a group of normal adults of different cultures, languages and social status were tested for lateralities and cognitive styles and then accessed for voluntary free associations concerning individual memory for odors. Associations were then evaluated by the subjects as neutral, negative or positive and according to different semantic fields (such as perfume, technology, home, medicine, sex,etc.) Similar to results from a study by Gilbert & Wysocki (1987), our data showed a high level of universality in the semantic organization of the olfactory semiosphere, though at the same time it was evident that cultural specifics and social constraints play a very important role (Ugolev,Chernigovskaya,1989). Social, cultural, educational and professional connotations were evident.

We also studied reactions to fragrances - their rejection or preferences - presented to the right- and the left ~~e~~ hemispheres (RH/LH) in normal adults, with professional testers included. Research on hemispheric involvement in professional olfactory degustation showed that RH personalities prevail at the cost of decrease of LH (correspondingly 0,55 vs. 0,45; P<0,05), while in the group of non-professional testers we see the opposite (0,32 vs. 0,68; P<0,01). This is not surprising, as testers use a Gestalt type of processing as their main tool.

In EEG monitoring of subjects with RH type of reactions (previously evaluated by special questionnaires) a reliable correlation of biopotentials was demonstrated in the RH when stimulated by odors preferable for them. Individuals of the LH type showed a correlation of biopotentials in the LH when stimulated by the odors rejected by them previously. The choice of preferable odors and colors of the Lüsher set was dependent on individual levels of anxiety. Classification and verbalization of colors showed significant differences in the types of strategies used by RH vs. LH subjects (Fig. 2-5).

The data suggest that most RH individuals demonstrate specific memory and verbalization of odors and that most professional testers of odors appear to be RH personalities. It also shows the important role of social and cultural as well as of linguistic background. Right hemispheric visual, auditory and olfactory processing seems to correlate with certain behavioral characteristics showing successful adaptation and resistance to stress and psychic or somato-psychic diseases and to adaptive behavior in general.

The correlation analysis of the EEG first derivative in RH and LH persons showed different patterns of the space synchronization of biopotentials, with preferable vs. rejected odors associated with alarm level. Individuals of RH type used Gestalt processing of all the items presented by sorting out the preferable; the rejected in this case will be the last in the row. LH persons on the contrary used a step by step rejecting strategy, so that the preferred odor is left to be the last in the row. Professional testers had lower latency thresholds of odor recognition and appreciation.

Hyperosmia as Hypersemia

Reminiscences and even *déjà vu* or vivid olfactory hallucinations caused by temporal lobe epilepsy were first described more than a century ago by John Hughlings Jackson. It is evident that hallucinations of all kinds are not the result of peripheral pathology, but a complex neurocognitive deficit. (Feigenberg, Zislin 2000). In maniac states with messiah and similar deliria, patients can achieve extremely extensive and thoroughly elaborated sensations of all modalities - sounds, odors and colors become unusually vivid, energetic and bright (Kuperman, Zislin, 2003). Instrumental measuring of peripheral thresholds does not show any changes, but brain imaging techniques do show cerebral activity in relevant brain regions (Whitton,1978; Sommer et al., 2003). The most frequent hallucinations are verbal, i.e. auditory, after which follow visual and tactile, while gustatory and olfactory are less frequent. The latter are also seen in depressive patients and those with epileptic seizures and Alzheimer's disease (Brill, 1932; Adams, Victor 1993; Martzke et al. 1997; Moberg et al., 1999; Sirota et al., 1999). In pathology semiotic functions are abnormal, and we find *hypersemia*, i.e. an increase of some signs' significance at the expense of others (Davtyan, Chernigovskaya, 2003). It can accompany and 'edit' *hyperosmia* in such patients.

Even in normal adults we find 'fits' of anosmia, hypo- or a hyperosmia, which appear to be associated with emotional states, endocrine status, and personal experiences, very often of a subconscious and limbic nature. Hypersomia is also found in patients in hyper-dopaminergetic states and in patients with Tourette's syndrome (Sacks, 1985) Smells are rarely neutral if the intensity is well above threshold. Still more amazing are behavioral changes when an olfactory stimulus is below the conscious threshold and is as if 'not perceived'. Olfactory memories and olfactory pictures can be so vivid that one could almost talk of controlled hallucinations.

Conclusion

Non-human signs are everywhere, and have been explored by different branches of semiotics (Sebeok, 1979; Hoffmeyer,1996). However, the human is the only living being knowing there are signs, i.e. having the ability of reflection and self-reflection and thus creating the semiosphere of a specific character (Lotman, 1990).

Language is a tool used to to categorize and therefore organize the fuzzy and vague continuum of perceived sensations. However, vast parts of sensory space do not even totally belong to specific sensory modalities, therefore causing synaesthetic (and aesthetic - *to rhyme*) sensations. Some are evolutionary so old and subconscious that they never had specific names (similar to most interceptor sensations). To construct a cognitive map of the olfactory and acoustic domain we should add personal latent knowledge to the verbal language that is so poorly elaborated in the case of a nonverbal semiotic sphere. Then we have a chance to regain the ability to perceive *'the brilliant smell of water, the brave smell of a stone, the smell of dew and thunder...'*

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