TORNADO EFFECT: INTEGRATIVE PHENOMENOLOGICAL DIMENSIONS TO THE NEURODYNAMICS OF SYNAESTHESIA

Anton V. Sidoroff-Dorso
Associate Professor (equivalent) of Moscow State Pedagogical University,
Invited Lecturer of International Institute of Management (the Open University, UK)
anton_sidoroff@mail.ru

Abstract: This paper is a sketchy proposal of a *neurodynamic model of synaesthesia*. We integrated the programme of neurophenomenology (F. Varela and E. Thompson) and the *non-representational* model of sensorimotor development (H. Dreyfus). This helped to explicate the bottom-up and top-down formative vectors. We conclude that the neural substrates of synaesthesia may be actualized through a two-phase collision of large-scale oscillatory activity of two dynamic cores, which we called *tornado effect*. Etiology wise, the genesis may coincide with *lateralized thalamo-cortical dysrhythmia* against the backdrop of the mass action of disproportionate brain synchronization (*maladaptive plasticity*) which leads to early sensory/perceptual incongruence and later development of synaesthesia.

Keywords: synaesthesia, neurodynamics, neurophenomenology, tornado effect, perceptual development, thalamocortical dysrhythmia, maladaptive plasticity.

INTRODUCTION

Synaesthesia is a time-related experience both in terms of its phenomenal interpretation and developmental origin. There has been much emphasis on its childhood rootedness and evocative nature but the associative ontology of the condition is strongly rejected due to the fact that no evidence is supplied of any conscious effort on the synaesthete's part.

Additionally, though self-report is an unavoidable springboard for scientific investigation of synaesthesia, the missing link or lack of contemplative bridge between lived experience and well-structured introspective guidance more than often leads to symptom/cause confusion which in the culture/nature dilemma is too detrimental.

We see the problem in the untangled character of synaesthesia as entailed by attention, consciousness and perception as dynamic heterogeneous notions, on the one hand, and the static tools and excessively analytic approach that the mainstream neuroscience proposes to address the issue, on the other.

That might explain the fact that the neuronal substrates and mechanisms of synaesthesia have not yet been properly hypothesized, as no present-day theory based mostly on the cognitivist assumptions of the neuronal doctrine and the neuroanatomic brain-mapping is able to come up with the explanation of synaesthesia in the form of parallel distribution of functions and large-scale synchronization for cohesive brain state transitions. However, this approach might turn out literally meaningful in our vision of the neural basis of the philosophically and scientifically intriguing phenomenon.

Despite the initial hardnosed resistance and because of the very nature of synaesthesia, its neuroscientific research is taking a U-turn to phenomenology as outlined first by the German neurologist Kurt Goldstein and philosophically elaborated by one of his short-term students, Maurice Merleau-Ponty. The present paper is a tentative proposal to apply *an integrative neurodynamic phenomenological model* (as proposed in Francisco J. Varela's stance of neurophenomenology) as a supplementary tool to address the neurophysiology of synaesthesia. The full description of the paradigm is elaborated in the following section of the paper. In conclusion, we will speculate about the complementary role of the neurodynamic theory of synaesthesia in finding its possible etiology and identify potential lines of further investigation.

1. (NEURO)PHENOMENOLOGY AND SYNAESTHESIA RESEARCH

Prior to the advent of MRI and other sources of objective data, self-report had long been the only source of scientific knowledge about synaesthesia.

Human beings need some validity of their own experience even in their own eyes. The German neurologist Kurt Goldstein questioned the unreflective reductionism and analytical bias, "By virtue of isolating, dismembering procedure one can readily abstract and single out from living phenomena those phenomena on the physic-chemical 'plane.' But the attempt to reintegrate the elements thus abstracted, to organise these split-off segments into the reality of living nature, is doomed to fail" (HOLGREGE, 1999).

However, a consistent crave for analyticity is part and parcel of the philosophy of science (BECHTEL, 1998) which, admittedly, makes it a rigorous tool with its distinctive domain and precise and parsimonious description, but the upshot of a reductionistic, over-analytical attitude is that its rigid logic through accumulation of inner controversies sooner or later is doomed to become defensive and complacent with no place for further advancement.

Cognitive sciences tend to focus on "*re-presentation*s in the head" (FRITZ ADOLF, ed., under review) but as soon as they start talking about neurophysiological observations of human thought, they tend to slip immediately into embracing the energy minima for human experience and contemplating the info storage to retrieve meaning. The pendulum swings.

Synaesthesia falls squarely between its initial adaptable variability and further cultural elaboration. It means, on the one hand, the elusiveness of its registration and complicated etiology, or/and the insufficiency of the precious minimal set of assumptions to elucidate it, on the other. That is what makes even a harder problem.

The emotional or noetic property (CYTOWIC, 1997) of the condition might make a prime example as this could come in all shapes and colours. Rationalisation, self-assertiveness, artistic acuity, social validation, religious affectation, retained insight or a combination of any of those or none at all, with no substantial means to back up.

Checking the patellar reflex, Goldstein asked his students to concentrate hard on trying not to kick. When they did so, the leg kicked out more than ever. The situation, he concluded, belongs to the reflex, so, it is part of the phenomenon (CREIG HOLDREGE, 1999).

Techniques to reconcile subjective and objective means of researching synaesthesia were first implemented by S. Baron-Cohen and J. Harrison by collecting fMRI and rCBF data in combination with synaesthetes' personal experience (BARON-COHEN, HARRISON, 1995). That stage didn't go beyond providing scientifically valid evidence of self-reports. Later, as a response to the clinician's ambiguous position in accumulating diagnostic data via introspective interviews and objective measurements, R. Cytowic proposed the idea of *nondismissive disregard* that was based on preventing the two flaws in clinical cases: (a) subjects may interpret their experience rather than report them; (b) investigators' assumptions are often theory-laden. Further, we would add that sharing the same cultural background as a point of reference, both parties can cross-fertilise preconceptions for shortcuts to explanation.

Consider, for instance, the so-called *additive* quality of synaesthesia (CYTOWIC, 2002; DAY, personal communication) which makes its nosological status yet more ambiguous. Evolutionary speaking, whatever the decisive argument for the adaptive value of consciousness might be, the phenomenal consciousness or "conscious awareness of the environment facilitates semantic comprehension and adaptive motor control actions in creatures like us" (FLANAGAN, 1992). However, with no extra *flexible* mode of action/reaction attached, any condition could hardly be called supplementary or, to use Block's terms (BLOCK, 1995), in the case of synaesthesia, P-consciousness does not seem to provide anything additionally *meaningful* to A-consciousness.

Among other useful insights, a significant advancement of Cytowic's proposal was that it was designed to be applied not only to synaesthetes rendering their experience but to the too-likely-to-be-biased inferences of experimenters and practitioners themselves. With regard to such a challenging condition as synaesthesia, whereby *symptoms* and *signs* are so idiosyncratic and, thus, elusive and intermingled, the theoretical lens that keeps sight of both sides of the story was really a stitch in time.

In the present paper, as a reifying development of Cytowic's nondismissive disregard, we propose a methodological tool of neurophenomenology with several advantages and further practical value.

Neurophenomenology was initially introduced by F.J.Varela as a method of structural integration of first person and third person accounts to address the hard problem of consciousness (VARELA, 1996).

Synaesthesia and consciousness share quite enough to make such a transfer methodologically justifiable. Both are only introspectively reportable, extremely subjective and explicitly culture-bound and, as we will argue further about synaesthesia, both are transient and time-related experiences.

Varela's programme capitalizes heavily on the phenomenology of perception by the French phenomenologist Maurice Merleau-Ponty (who himself was Goldstein's student for a little while). Philosophically, phenomenology can be understood as the project of providing a disciplined, methodical characterization of the phenomenal invariants or categorical features of lived and well-articulate experience (perception, mental imagery, etc.) in all of its multifarious forms (VARELA, SHEAR, 1999).

Neurophenomenology as a research programme applies phenomenological investigations of the phenomenal structure of subjective experience to guide neuroscientific investigations of the brain activity subserving consciousness (VARELA, 1996). Methodology wise, this approach is devised to embrace in a rigorous and extensive way first person reports on subjective experience as a heuristic path to describe and quantify the large-scale neurodynamics of consciousness (LUTZ et al., 2002).

Within a broader theoretical framework, neurophenomenology provides an embodied/enactive and large-scale dynamic dimension to the neurophysiology of consciousness (THOMPSON, VARELA, 2001). To incorporate self-report into cognitive neuroscience, it addresses the following three contingencies: (i) bias and inaccuracy of first-person reports; (ii) proneness of first-person report generation to modify the reported experience; and (iii) an 'explanatory gap' in our understanding of how to relate first-person, phenomenal data to third-person, behavioural data. (LUTZ, THOMPSON, 2003).

Further, the experimental level of studying conscious phenomena should be based on the principle of *reciprocal constraints* that presupposes that the subjects' self-report and the neuroscientists' objective data should augment and refine each other in a mutual and incremental way (LUTZ, THOMPSON, 2003).

In 2002, the framework of neurophenomenology led to integration of the two types of data into an anticipatory model of epilepsy. The model "provided strong evidence that it is possible to detect a *pre-seizure state in the neuronal dynamics* several minutes before the electro-clinical onset of seizures" (LA VAN QUYEN, 2002).

As applied to the synaesthesia domain, neurophenomenological strategy emulates the nondismissive disregard proposal in covering the unreliability of introspection and theory-laden assumptions. However, it hugely updates that scheme in terms of being more fully integrated in a cohesive battery of related techniques and extending beyond conventional boundaries into *reflective* cooperation between investigators and subjects.

In brief, neurophenomenology is based on the synergistic use of three fields (LUTZ, THOMPSON, 2003):

a) first-person data from the careful examination of experience with specific first-person methods.

We apply this stage in Part 2 of the present paper as a critique of exceedingly analytical cognitivist/ representativist approach to understanding synaesthesia with special reference to its objective and subjective records;

b) formal models from dynamical systems theory, grounded on an enactive approach to cognition.

This will be presented in Part 3, in which we propose an application of the non-representational model of sensorimotor skill as described by H. Dreyfus (DREYFUS, 1992) to perception and synaesthesia.

c) neurophysiological data from measurements of large-scale, integrative processes in the brain.

Finally, this epistemological field will be contemplated in Part 4 that describes our tentative approximation to *the neurodynamic theory of synaesthesia* from the perspective of the solidified systems analysis and with its extension to brain-body-world interrelations in the neurobiological paradigm of *radical embodiment*.

Throughout this paper, we try to reinforce the idea that large-scale neurodynamic perspectives are crucial to the task of spotting the spatiotemporal integration of various analytically induced activities (such as attention, emotional disposition, intentional objectification, sensory dominance, motor activity, etc.) for which the classic projectional and cognitivist model of these strictly compartmentalized activities is now turning drastically insufficient.

The current research data on synaesthesia that do not regard *time* and *self-organisation* as equally important variables is doomed to overlook what it adds to or derives from individuality, emotion or meaning. Such unreflective reductionism cannot claim to be directly applicable for humans as the only ontological species whose inner state in times of inspiration may have no cause beyond itself.

To our mind, the opposite type, scientific holism or integrative ontological framework, should not be interpreted as condemning the analytical method but as cautioning against the self-serving (and self-limiting) analytical *trend* of thought.

2. PERTINENCE OF PARADIGM SHIFT

Though with sparse and patchy direct correlations on hand, neuroscience is now hardly in two minds as to whether specific cognitive acts, not to say meaningful experience, should at least be accounted for by the metastable integration of multiple, widely distributed, constantly interacting regions of the brain. Therefore, any theoretic assumption about the neural substrates of attention-related, time-dependent phenomenal events must take into consideration the coherent operation of wide-spanning brain activity and include consciousness as a variable.

In his 2002 article, Richard Cytowic speculated that his longtime research of synaesthesia had led him to think in favour of a model of brain functioning known as the distributed system that views neural activity not as linear processing but multi-level, concurrent activation of evenly distributed sub-tasks (CYTOWIC, 2002). As this system hinges to a greater degree on relative topology rather than function-to-spot localization, Cytowic criticizes synaesthesia researchers for their overdue concentration on specific brain areas because "scans mislead us by emphasizing peak probabilities which we misconstrue as fixedly anatomical" (CYTOWIC, 2002). Thus, the mechanism of synaesthesia is not a matter of place but overall process.

Cytowic is not alone in the search for a more embracing neuroscientific paradigm of synaesthesia. See, for instance, Gregg Rosenberg's stance that synaesthesia proves that phenomenal properties can change independently of representational properties (ROSENBERG, 2004) or the practical implication of the projector/associator distinction and its related degree of automaticity (DIXON et al., 2004). And though the systems analysis has been present for a while in both cognitive science and neurophysiology, these fields are still dominated by representationalism and unreflective empiricism.

These models take much after the organ-based anatomy considering the nervous system as strictly compartmentalized areas with attributed functions, though these functions are *deduced a priori*. Apart from the theoretic impediments that cognitivism (following H. Dreyfus we give this term to all intellectualist/reductionist/representational trends) poses for the study of consciousness, this paper is based on the domain-specific issue that we consider vital to be placed centre stage in synaesthesia research. The question is: Can we completely isolate qualia (perceptive features) in lived phenomenal experience?

The mainstream definition of synaesthesia is a condition in which otherwise normal people experience the blending of two or more senses (RAMACHANDRAN, HUBBARD, 2003) or linkage of otherwise individual percepts. Even in specialist titles, synaesthesia is defined as hard-wired neural connections from one perceptual system to another (BARON-COHEN et al., 1993; HARRISON, 2001) or as "an experience in which stimulation in one sensory or cognitive stream leads to associated experiences in a second, unstimulated stream" (HUBBARD, 2007). But what is secondary in all such definitions (read, diagnoses) is the personal memorability, emotional charge, attentional distribution, systemic and skill-related nature, characteristics and degree of binding, i.e. the qualitative totality of synaesthetic events.

The reductionistic bias is glaring in the field of synaesthesia exploration. For the most part the neurology of synaesthesia is contemplated in the vein of cognitivist emphasis on precise function-related area (modularity) and small-scale architecture (localisation) (HUBBARD, 2007). But neither architecture (should be adjacent) nor location (may be non-adjacent) explain synaesthetes' idiosyncrasies and explicate the condition in a coherent way.

A careful comparative study of a large pool of synaesthetes demonstrates that the dominant contemporary theories are hardly in line with the actual statistics. For example, some synaesthetic experiences involve non-adjacent cortical areas (olfactory-to-colour - 6.7%; aural-to-gustatory – 5.4%) or can include idiosyncratic, emotion-laden and even multifaceted eidetic imagery (DAY, 2004). Another example might be the commonsense version of olfactory-to-taste synaesthesia when two anatomically isolated senses intermingle in almost all human population with no proven direct cross-wiring at all (PFEIFFER, et al., 2005).

At the cognitive macro-level, the present day dominant theories do not seem to explain the phenomenal disproportion of inducer/concurrent experience, though the relative simplicity of concurrents in comparison to their inducers has been emphasized not once (CYTOWIC, 1997, 2002). Moreover, such an input/output paradigm neglects the cases of memory-induced or emotionally mediated synaesthetic phenomena. But selectively ignoring and, thus, accumulating discrepancies reductionism starts rendering itself utterly dualistic.

So far, even the so called synergistic approach that does not go beyond coupling experimental findings with synaesthetes' first-person account is still constrained to the limits of the much-cherished framework of associated qualia, looking for "a schematic representation of the cortical pathways that…are involved in the activation of the synaesthetic colour *red*" (SMILEK, DIXON, 2002).

Following this theory-laden assumptions some researchers go as far as to predict the discovery of the synaesthesia gene (comparable to the creativity gene) that should get phenotypically expressed due to its sufficient concentration in relevant cells (SMILEK et al. 2002).

Put together, these hot-button descriptions are much out of sync with the lived experiences of synaesthesia that are usually included in the first-person accounts accompanying the studies but dispensed with as redundant leftovers somewhere on the way.

We would not claim that scientific analysis per se is destructive. Neither would we call for any silver bullets. In this paper, we would like to make a tentative proposal to extend the frontiers of analytical investigation so that the issue of synaesthesia could get the appropriate scope of relevant causal mechanisms. In our view, the hope for the "Grand Unified Theory" of synaesthesia might be possible if all the idiosyncratic and experiential qualities are taken into account which might lead to starting such an exploration as if "from above", that is, with analyzing the totality of brain dynamics.

3. PERCEPTION AS A SKILL

The classic cognitivist theory of perceptual development and learning is based on the recursive mechanism of *external noise exclusion* alongside or independent of *stimulus enhancement*, all hypothetically resulting in *gain control*. The whole process is explicitly *representational*, i.e. the practiced operation should be discriminated in the form of an input stimulus building up the feedback loop. One of the major contradictions of such a model is that though gain control should be the primary measurable variable because its change, "specifically in multiplicative internal noise, lead to effects that appear larger (on a log scale) at higher criterion performance [meta-skill] levels (DOSHER AND LU, 1999). To date, changes in gain control due to perceptual learning have not been observed" (quoted in ITTI, 2005).

Another flaw of the conventional theory is that in infant development of the perceptual domain, limitations of inputs, specifically to the sensory system, are viewed as handicaps to overcome (TURKEWITZ, KENNY, 1982). As a result of ignoring the self-pacing and self-directing principles of human organisms at both ends (gain control directly correlates with self-limitations), the cognitivists' model of perception is based on the notion of *receptive* (passive) *field* structured in a certain way so as to preferentially accumulate the *representations* of objects or events by strictly *feature*-specialized sensory neurons (BARLOW, 1972) that process the inflow of *data* in a *hierarchical* way (HUBEL, 1988).

Nothing of that kind happens in reality. As anyone who learnt factor analysis or acquired driving skills knows that despite the fact that some instructional algorithms should be provided at first, the rest of upgrading abilities comes through approximation, subtle imitation and *gradual* adjustment. Even better so, when it comes to practicing a foreign language.

In 1992, as a bridge between phenomenology, human/environment interaction theory, and cognitive science, H. Dreyfus proposed a *non-representational* model of skill acquisition. That was his response to the challenge of self-organising properties and learning in AI (DREYFUS, 1992). Indeed, as Dreyfus simply puts it, "There are just too many features, so the selection of the relevant features would require that one had already subsumed the situation under the relevant concept" (CARMAN, HANSEN, 2006). In line with this judgement, case-based learning by analogy is also intrinsically flawed as to identify similarity we should already have the necessary background knowledge against which to compare.

For instance, the non-representational character of perceptual learning may be supported by the results of experiments in acquiring the ability of perceptual discrimination between the contrast values of the central and the surrounding stimuli (ADINI, et al., 2002). The scientists concluded that for this function only one level of visual processing should be involved (the primary visual cortex V1) which suggests that perceptual learning does not necessarily require lower-to-higher or higher-to-lower interactions between different cortical locations at different stages of visual processing.

What is equally important for our study is that "an impression can never by itself be associated with another impression. Nor has it the power to arouse others. It does so only provided that it is already *understood*" (MERLEAU-PONTY, 2002). Therefore, phenomenologically speaking, actual associations are pre-cognitively linked or, put otherwise, we have associations through experiential dissociation first. Thus, in phenomenal terms, each situation directly shows up *perspectivally* and segued into the next.

What kind of pre-knowledge is meant here? This one is much better interpreted in light of the notion of living organisms' *self-organisation* (*autopoiesis*) introduced by Maturana and Varela (MATURANA, VARELA, 1980). Such organisms are causally autonomous and capable of changing the parameters that govern their own interaction with their environment by means of the so called autocatalytic feedback (DEPEW, WEBER, 1999), in this respect perception should be considered not as direct representational, content-matching correspondence but as a self-reliant network of secondary properties that non-specifically reacts to environmental stimuli. To specify this, "Physical stimuli act upon the organism only by eliciting a global response which will vary *qualitatively* when stimuli vary quantitatively; with respect to the organism they play the role of occasions rather than of cause; the reaction depends on their vital significance rather than on the material properties of the stimuli... One cannot assign a moment in which the world acts on the organism, since the very effect of this 'action' expresses the internal law of the organism (my emphasis) (Merleau-Ponty cited by Dreyfus) (CARMEN, HANSEN, ed., 2006). It might be proved by the fact that we can easily identify the correlations between colours that we attribute to objects and our brains' related neuronal activities but not the actual wavelengths of those colours (MATURANA, VARELA, 1992).

It is important to note here that in an organism as a self-organising system, binding may (and should) come *before* qualia in the form of never-ending alertness for rules and categorical perception, which in itself is evidenced by permanent perceptual/ cognitive openness (intentionality) in the form of psychophysical tension. This is evidenced by the theory of perceptual development according to which "infants *actively* seek information that comes to specify identities, places, and affordances[1] in the world…. Perceptual learning is viewed as a selective process, beginning with exploratory activity, leading to observation of consequences, and to selection based on two criteria, an affordance fit and reduction of uncertainty, exemplified by detection of order and unity in what is perceived" (GIBSON, PICK, 2000).

Another related line of research that stands in strong opposition to the cognitivist data-based model of perception is the direct view (which includes a combination of ecological and sensorimotor approaches). According to Varela's variant called *enactment* (VARELA, et al., 1991), an organism's perception is strictly congruent with its environment as both share the same situational ontology (*structural coupling* through evolution and individual development) (THOMPSON, 2007).

Specifically, as Thompson argues in his case against the computational model of vision (THOMPSON, 1995), "the biological function of colour vision is not to detect surface reflectance, but to provide a set of perceptual categories that can apply to objects in a stable way in a variety of conditions."

One of the conclusions that is important for our purposes is that perception is an *active* process of making sense of the world and presupposes holistic (on the part of the organism) non-linear processing.

The non-representational model of perceptual development combined with its nonlinear processing indicates the possibility of marginal sensory experience within a heterogeneous field of attention. However, this poses a contradiction in the case of synaesthesia because, on the one hand, it seems to be top-down, concept-based and paradigmatic, on the other, its associative nature appears to be bottom-up, reflex-like and elemental.

This paradoxical status of synaesthesia may be resolved if one takes into consideration its temporal (at least, two-phase) character. The first phenomenal phase (inducer phase) is triggered by a complex stimulus with minimal skill-like recognition for which some exposure to culture-specific situations is required. We would argue that at this phase the "synaesthetic quale" yet belongs to the sensory mode and has just an orientational potential, it is only at the second phase (concurrent phase) that the quale gets its categorical meaning as part of the colour (or any other) system, therefore, starting to belong to perception proper. If the synaesthete was not informed in intersubjective commerce that they perceive something in a different manner, the latter would not have taken shape and added up to the overall perceptual skill as augmentative, secondary component.

According to H. Dreyfus, the best way to emulate the evolution of human experience and cognition in AI is the model of multiple neural networks (CARMEN, HANSEN, ed., 2006) that at their most precise leads us to the variant of dynamic systems analysis.

[1] Affordances may be viewed as the organism's pre-cognitive associations between objects in the environment and its needs and abilities.

4. "TORNADO EFFECT" THEORY

To date, all the synaesthesia theories are strictly modular and implied local-to-global generalizations. These assumptions are parsimoniously based on functional coherence within the brain areas (perceptual systems) which in turn should imply a tacit notion of structural similarity. Hence, in terms of the cognitivist approach this similarity could be deduced as nothing other than "direct, hard-wired neural connections" (WARD, SIMNER, 2003). One exception to the trend can be the "hyperbinding" theories (EMRICH et al., 2002; ESTERMAN at al., 2006) but they tend to theorize synaesthesia in terms of cross-modular activation putting the notion of individual (bound or unbound) qualia/percepts to the fore. Such approaches capitalize on the naïve (in the phenomenological sense) retrospective interpretations of personal experience, not on the undisrupted development of perceptive skills where *binding comes first*. Besides, this misconception may stand in the way of finding the neurophysiologic basis of synaesthesia (HUBBARD, 2007).

In order to understand synaesthesia in relation to individual subjective experience and as a final step of the neurophenomenological paradigm, we suggest analyzing it within the framework of neurodynamic correlates (VARELA, THOMPSON, 2002; COSMELLI, THOMPSON, 2007). This approach not only can provide the maximum scope of relevant variables but also help to include the previously immeasurable "additives" such as meaning, intention, and attention.

Here, we will present the more or less solidified theory of neurodynamics with marginal and much debatable issues omitted. The main emphasis will be on the brain-body-world neurodinamic interpretation as proposed by Francisco J. Varela (VARELA et al., 2001) and Evan Thompson (THOMPSON, VARELA, 2001). We will also turn to other neurodynamic models (FREEMAN, 1999; EDELMAN, TONONI, 2000; ENGEL et al., 2001) that we hold relevant for understanding the causality of synaesthesia.

Neurodynamics, or the systems analysis of brain functioning, capitalizes on the following assumptions. First and foremost, the nervous system in general and the brain in particular are analyzed as a nonlinear dynamical system with *every* neuron activated (zero frequency rate is "silent consent") at any given moment of time (ASHBY, 1952). The processual pattern of any neuron is influenced by its own activation timeline and that of any other neuron, thus constituting the mass action of the whole system (FREEMAN, 2004). Any two neurons in this model are always either in direct or indirect interaction that is shaped by the weight of the synapse that connects them or the common denominator of the synaptic weights of all the intermediary neurons between them. Thus, the overall synaptic pattern determines the main set of order parameters (collective variables) in the nervous system (ARBIB, 2002). It must be added that the system is not considered to be isolated but is constantly affected by external sensory inflow.

As no area in the brain has been singled out as the highest level in terms of mass action, every local and remote activation will be dynamically (weak as it may be) related. To distinguish the functionally and spatiotemporally correlating clusters of neurons, the systems approach uses the notion of dynamic cores. A dynamic core is defined not as a thing or location, but as a process of neural integration unfolding in time in fractions of milliseconds (EDELMAN, TONONI, 2000). For instance, the concurrent activation of right parietal, anterior cingulate and occipital cortices can correlate with picking an object in the visual field (MESULAM, 1999).

The demarcation of a distributed, spatiotemporal pattern against the background activity of the brain is realized through oscillatory synchronicity. Such self-limiting, transient but recurrent coordinations are considered to be correlative with the moment-to-moment emergence and formation of conscious experience (THOMPSON, VARELA, 2001; COSMELLI et al., 2007). It was proposed that such dynamical cross-activations are mediated by the phase synchrony (across the beta and gamma ranges) for recognition and consciousness (VARELA et al., 2001) and may be sustained through gamma-oscillatory thalamo-cortical interaction (LLINAS, RIBARY, 2001). In this respect, synchrony means precise phase-locking rather than the fMRI spectral coherence that do not discriminate phase and amplitude components (THOMPSON, VARELA, 2001).

The self-organising character of the nervous system complements the enactive dynamics of perception, and supports the idea that the emergence of a quale may be secondary to the formation of binding:

"The pure sensation of red is a particular neural state identified by a point within the N-dimensional neural space defined by the integrated activity of all the groups of neurons that constitute the dynamic core. . . The conscious discrimination corresponding to the quale of seeing red acquires its full meaning only when considered in the appropriate, much larger, neural reference space" (EDELMAN, TONONI, 2000).

Another feature significant for neurodynamics is that the large-scale spatiotemporal patterns (dynamical cores) reveal the statistically relative interplay of two formative principles – functional *segregation*, mechanism of promoting a particular ensemble of active neurons, and cooperative *integration*, i.e. communal functioning of neurons. All in all, the framework offers a plausible mechanism of juxtaposing the local functional specificity in specialized cortical areas to the constraint of overall nervous activity. In so doing, it establishes the neurophysiologic basis of *circular/reciprocal causality* with equipollent but functionally asymmetrical downward and top-down forces.

Following Merleau-Ponty, Varela and Thompson propose that cognitive processes are not brain-bound but integrate the whole body embedded in its environment (VARELA, THOMPSON, 2001). The *radical embodiment* dimension of the neurodynamics comprises three "cycles of operation": a) *organismic regulation* of homeostatic biochemistry and molecular level; b) *sensorimotor coupling* of organism/environment circular interaction; c) *intersubjective interaction*. It is the latter two that, to our mind, may contribute to the origin of synaesthesia (see above).

Following Dreyfus' description of human/environment interaction and non-representational skill acquisition, we conceptualise perception as an overall, ongoing time-related skill that is reinforced through feedback by narrowing the initially chaotic (mental) activity to the intended outcome. The *differentiation* of senses in infants (MAURER, MAURER, 1988) may be examples of its early stages. Further stages of perceptual development may include incorporating meaningful skill-based variations of intensity grading and combination of basic sensations.

Seen from the *enactive* neurodynamic viewpoint, perception has an active, two-way character: it "underscores the importance of two interrelated points: 1) perception consists of perceptually guided action and 2) cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided" (VARELA et al., 1991). In such understanding, representation is not considered as constructional but embodied or enacted twofold: (a) bottom-up or through ontological unity with the environment (organismic regulation – sensorimotor coupling); and (b) top-down or through symbolic communication or imitation (intersubjective interaction - sensorimotor coupling).

In this respect, colour or any sensory unit is both a result and foundation of human/environment interaction. So, it will be no exaggeration to infer that, analytically put, some perceptual properties, or "qualia", may be endogenous and have no direct correspondence in reality.

Usually perceptual categories are assembled from locally different brain areas with their functional integration temporally encoded, thus, bringing about the uniqueness, transience and combinability of human experience. Even spatially overlapping neuronal networks may or may not be recognized as functionally coordinated. It is due to their unique temporal code that they may be attributed through synchrony to the same function (FERSTER, SPRUSTON, 1995). The same network can be engaged in different ensembles through altering their temporal activation and frequency coding (EDELMAN, 1987).

Implementing this paradigm, we could hypothesize that during the early stage of the formation of perceptive skills, the weights (total charge) of the activated set of neurons distributed across the brain might capture or *resonantly block out* another neuronal population which is otherwise (in a different phase-lock pattern) strongly bound in a perceptively different experience.

The former spatiotemporal pattern (dynamic core, to borrow Edelman's term) may "overshadow" the latter because of the three reasons. First, the weights of the former, more cognitively involved and systemic pattern have more charge potential and evoke disproportionate brain synchronization (discussed below); second, because the latter, more primitive but also systemic pattern, has not yet been fully established. When both patterns reach adaptable maturity, the resulting "percept" happens to be a form of *extrapolation* of both sensory-cognitive paradigms. It may explain why synaesthetes themselves report that have never experienced it in real life and describe their sensations only in approximate terms. Third, the overlapping sector is attentionally marginal, that is, environmentally irrelevant. It does not fall directly into the feedback loop, does not disrupt adaptability and is not recognized initially as wrong, if otherwise – it gets corrected immediately. The more systemic (in terms of categorical extrapolation) the spatiotemporal overlapping itself is, the deeper these patterns "grow" into each other.

Moreover, this *resulting* "percept" or "system of percepts" become introspectively recognized as belonging to different perceptive systems at a much later stage and it is *only* through personal *intersubjective* reflexive communication with other individuals that synaesthetes themselves get to know about their perceptive discrepancies.

Other cases of various attentional depth/conscious involvement, sensory factors or cognitive character might go unnoticed as eccentric (déjà vu, eidetism, idée fixe etc.) or classified to be of different nosology (epilepsy, schizophrenia, etc.). Synaesthesia has its marginal status because it is interpreted as weird against particular cultural practices and intersubjective conditions that in turn appropriate the physiological schemes of perception (sensoriums).

Why can't these discrepancies get corrected later on? In line with the proposed model we would not exclude the possibility of partial (*laterally* asymmetrical) thalamocortical dysrhythmia (LLINAS, et al., 1999) whereby the oscillatory connectivity between the thalamic cells and the corresponding neocortical (layer IV) areas gets resonantly desynchronized. The unilateral asymmetrical asynchrony might lead to perceptual salience disturbance *functionally projected* on the related cortical regions. This might take place against the backdrop of the mass action of disproportionate brain synchronization (*maladaptive plasticity*) which in turn leads to sensory/perceptual incongruence, though the precise details of the neuronal mechanism of lateralized functional distribution and the hypothesis itself needs further consideration and more solid evidence.

Our assumption that might be proved by the segregation/integration process of the sensorimotor cycle of operation (THOMPSON, VARELA, 2001) is that as both dynamical cores (spatiotemporal patterns) are the result of the mass action of the whole brain's activity and the perceptive skill formation takes place in the ongoing process of self-orientation chronologically much earlier. Thus, they get integrated in more sophisticated mechanisms of adaptation and "get sealed" within other more complicated dynamical cores that are mediated by transient neural assembles of sensory/motor coordination (and starts belonging to the peripheral afferent-efferent system). Thus, passing the critical mass action (and sensitive period) of the corresponding sensory system, they get relatively stuck in time and context, though the reciprocal but apparently asymmetrical interconnection is not excluded due to an individual's secondary self-reflecting ability (in the sensorimotor cycle).

The systems analysis (that is also applied in weather forecasting) reveals the brain dynamics of synaesthesia in the form of a vortex-like figure, a tornado of time-spanning synaptic activity with the visible part mistakenly rationalized for the epicenter. Free from overly analytical, unreflective bias, our theory presupposes parallel rather than linear processing, thus turning large-scale brain activation into a subtle (tornado-like) collision effect of two dysrythmic dynamical cores (spatiotemporal patterns) *of perceptual skill formation*, whereby the cortico-cortical correlations may be activated not due to direct passive physiological cross-wiring as, for instance, S. Baron-Cohen and others argue (Baron-Cohen, 1996; Ramachandran, Hubbard, 2001; Hubbard, 2007), but to cumulative incremental firings resulting in reciprocal differential disturbances in not necessarily adjacent or/and insufficiently myelinated areas.

It is important to mention here that we are not describing the process in the geometrical sense of brain architecture but in terms of *spatiotemporal distribution* and *phase synchrony* of the functions involved. This model does not presuppose physical proximity as such, not to say direct hard-wiring of activated neurons or nodes, but only their synchronous discharging at a particular moment of time. In this respect the adjacency of the activated areas makes their mutual phase-locking statistically more opportune due to the more complementary demands of the environment but long distance synchronization is enabled through the same mechanism.

INTEGRATION

The present paper is a sketchy attempt to propose a neuronal dynamic systems analysis as an explanatory framework for the neurophysiology of synaesthesia with special reference to its phenomenal idiosyncratic experience. To achieve this goal, we implemented the programme of neurophenomenology as proposed by F. Varela and E. Thompson in complementary compliance with other major neurodynamic theories (Edelman, Freeman, Llinas). In contrast with the mainline modular and predominantly cognitivist views in neuroscience that fail to elucidate some crucial aspects of synaesthesia, the *neurodynamic approach* provides a coherent battery of techniques and emphasizes wide-scale and transient brain functioning that proved instrumental for the neural mechanisms of the temporal and consciousness-related condition of synaesthesia.

In accord with the neurodynamic framework of *radical embodiment*, we borrowed H. Dreyfus' *non-representational* model of sensorimotor skill development and integrated it into the three cycles of operation. This resulted in a *two-phase sensory/perceptual structure* of the phenomenology of developmental synaesthesia which strictly distinguishes its *bottom-up* and *top-down* formative factors as (a) an adaptable variety of phenomenal phenotype; but (b) culturally distinct and elaborated experience.

Further, the non-representational and self-organizing property of perceptual development helps to explain the heterogeneity of attentional salience and its individual unfolding character (whereby binding may pre-form qualia). The notion of perceptual development as an overall, skill-related orientational activity embraces both the environment-dependent variable and the neural substrates of the condition under review.

In this respect, we tentatively hypothesized that these possible neural substrates that underlie the phenomenal experience of synaesthesia may be actualized through a collision of large-scale oscillatory activity of two (or more) spatiotemporal patterns (dynamic cores), the process we figuratively called *tornado effect*. The early phase comprises the period when the primary dynamic core corresponding to skill-related activity (music, reading, language recognition, etc) *resonantly blocks out* the secondary, more receptive core of categorical perception. As the subject develops more complicated ways of interaction, both categorical perceptual paradigms "grow into each other", retaining permanently their common systemic backbone. The later phase includes the skills of interpersonal communication (empathy and intersubjective reflection), that drive the subject to uncover their perceptual discrepancies and start deliberating them in the pursuit for appropriate cooperation.

In our model, the top-down or culture-related forces take a twofold shape: (1) the subject's environment objectifies the sensory/perceptual disturbance through demands they encounter and primary informational mode they use (with compensatory concurrents prevalently in the dominant sensory modality); (2) the subject's intersubjective reflective communication with others reveals and emotionally galvanises the uncovered discrepancies.

As a tentative variant of etiology, we could theorize that the described genesis is triggered or accompanied by *lateralized thalamo-cortical dysrhythmia* against the backdrop of the mass action of disproportionate brain synchronization (*maladaptive plasticity*) which in turn leads to sensory/perceptual incongruence and, in the integrative large-scale, results in the development of a compensatory mechanism known as synaesthesia.

The systems analysis (that is also applied in weather forecasting) reveals the brain dynamics of synaesthesia in the form of a vortex-like figure, a tornado of time-spanning synaptic activity with the visible part mistakenly rationalized for the epicenter.

Free from overly analytical, unreflective bias, our theory presupposes parallel rather than linear processing, thus turning large-scale brain activation into a subtle (tornado-like) collision effect of two dynamical cores (spatiotemporal patterns) of perceptual skill formation, whereby the cortico-cortical correlations are activated not due to direct passive physiological cross-wiring but to cumulative incremental firings resulting in reciprocal differential disturbances in not necessarily adjacent or/and insufficiently myelinated areas.

Anton V. Sidoroff-Dorso. Associate Professor (equivalent) of Moscow State Pedagogical University; Invited Lecturer of International Institute of Management (the Open University, UK). Holds a full degree (Hons) in EFL and Intercultural Communication. Research focus in anthropology of language and intersubjectivity. Independent researcher of synaesthetic foundations in cultural anthropology (senses and cognition). In 2008, participated in the Conference on Synaesthesia in Kazan ("Synaesthesia: Commonwealth of Senses and Synthesis of Arts"). Currently engaged in the project and a series of articles *Synaesthesia across cultures*.

Acknowledgements
I wish to express my gratitude to Dr. Sean A. Day, the American Synesthesia Association, for access to the Synesthesia List and referring me to the appropriate addressee of this paper.

I also deeply appreciate the help of the participants of the Syn-list (http://home.comcast.net/~sean.day/) who agreed to share their experience via interviews.

REFERENCES

ADINI Y., SAGI D., TSODYKS M. (2002), "Context-enabled learning in the human visual system", in *Nature*, Vol.415, pp. 790-793.

ARBIB M. A. (2002), *Handbook of brain theory and neural networks*, MIT Press, Cambridge, MA.

ASHBY R. (1952), *Design for a brain*, Chapman-Hall, London.

BARLOW H.B. (1972), "Single units and sensation: A neuron doctrine for perceptual psychology?" in *Perception*, Vol.1, n.4, pp. 371 – 394.

BARON-COHEN S. (1996), "Is There a Normal Phase of Synaesthesia in Development?" in *Psyche*, Vol.2.

BARON-COHEN S., HARRISON J. (1995), "Synaesthesia: reconciling the subjective with the objective", in *Endeavor*, Vol.19, n.4, pp. 157-160(4).

BARON-COHEN S., HARRISON J., GOLDSTEIN L., WYKE M. (1993), "Coloured Speech Perception: Is Synaesthesia What Happens When Modularity Breaks Down?", in *Perception*, Vol. 22, pp. 419-426.

BECHTEL W. (1998) *Philosophy of science: An overview for cognitive science*, Erlbaum, Hillsdale, NJ.

BECHTEL W., HERSCHBACH M. (in press) "Philosophy of the cognitive sciences", in ALLHOFF F. (ed.) (under review) *Philosophy of the special sciences*, SUNY Press, Albany, NY.

BLOCK N. (1995), "On a Confusion about a Function of Consciousness", in *The Behavioral and Brain Sciences* Vol.18, n.2.

COSMELLI D., LACHAUX J., THOMPSON E. (2007), "Neurodynamic approaches to consciousness", in ZELAZO P., MOSCOVITCH M., THOMPSON E. (eds.) (2007), *The Cambridge Handbook of Consciousness*, Cambridge University Press.

CYTOWIC R. (1997), "Synaesthesia: phenomenology and neuropsychology – a review of current knowledge" in *BARON-COHEN S., HARRISON J.* (eds.) *"Synaesthesia: Classic and Contemporary Readings",* Blackwell, Oxford, pp. 17-39.

CYTOWIC R. (2003), "The Clinician's Paradox: Believing Those You Must Not Trust" in *Journal of Consciousness Studies*, Vol.10, n.9-10, pp.157-166.

CYTOWIC R. (2002), *Synaesthesia: a Union of the Senses. Second edition*, Springer-Verlag, NY.

DAY S. (2009), the Synesthesia List, http://home.comcast.net/~sean.day/html/the_synesthesia_list.html

DAY S. (2004), *"Trends in Synesthetically Colored Graphemes and Phonemes - 2004 revision"* http://home.comcast.net/~sean.day/Trends2004.htm

DEPEW D., WEBER B. (1999), "Self-Organizing Systems" in WILSON R., KIEL F., (eds.) (1999), *The MIT Encyclopedia of the Cognitive Sciences*, MIT Press, pp. 737-738

DIXON M.J., SMILEK D., MERIKLE P. (2004), "Not all synaesthetes are created equal: Projector versus associator synaesthetes" in *Cognitive, Affective & Behavioral Neuroscience*, Vol.4, n.3, pp. 335-343.

DOSHER B.A., LU Z.L. (1999), "Mechanisms of perceptual learning", in *Vision Research*, Vol. 39, pp. 3197-3221.

DREYFUS H. (1992), *What Computers Still Can't Do*, MIT Press, NY.

DREYFUS H. (2004), "Merleau-Ponty and recent Cognitive Science", in CARMAN T., HANSEN M. (eds.) (2004), The Cambridge Companion to Merleau-Ponty, CUP, Cambridge.

EDELMAN G. M. (1987), *Neural Darwinism*, Basic Books, NY.

EDELMAN G. M., TONONI G. (2000), *A universe of consciousness: How matter becomes imagination*, Basic Books, NY.

EMRICH H., ZEDLER M., SCHNEIDER U. (2002), "Binding and hyperbinding in intermodal perception and synesthesia" in *Zeitschrift für Semiotik*, Vol. 24, n.1

ENGEL A. K., FRIES P., SINGER W. (2001), "Dynamic predictions: Oscillations and synchrony in top-

down processing", in *Nature Reviews Neuroscience*, Vol.2, n.10, pp. 704-716.
ESTERMAN M., VERSTYNEN T., IVRY R.B., ROBERTSON L.C. (2006) "Coming unbound: disrupting automatic integration of synesthetic color and graphemes by transcranial magnetic stimulation of the right parietal lobe" in *Cognitive Neuroscience*, Vol.18, pp.1570-1576.
FERSTER D., SPRUSTON N. (1995), "Cracking the neuronal code" in *Science*, Vol.270, pp. 756-757.
FLANAGAN O. (1992), *Consciousness Reconsidered*, MIT Press.
FREEMAN W. J.(1999), *How brains make up their minds*, Weidenfeld and Nicolson, London.
FREEMAN W. J.(2004), *Mass action in the nervous system* (2nd ed.), at http://sulcus.berkeley.edu.
HARRISON J. (2001), *Synaesthesia - the strangest thing*, OUP, Oxford, England.
HOLGREGE C. (1999), "Seeing Things Right-side Up: The Implications of Kurt Goldstein's Holism", in *In Context*, n.2, pp. 14-17.
HUBBARD E. (2007), "Neurophysiology of Synesthesia", in *Current Psychiatry Reports*, Vol.9, pp. 193-199.
HUBEL D. (1988), *Eye, Brain and Vision*, Scientific American Library, NY.
ITTI L., REES G., TSOTSOS J. (2005), *Neurobiology of Attention*, Elsevier Academic Press, London
LE VAN QUYEN M. (2003), "Disentangling the dynamic core: A research program for a neurodynamics at the large-scale", in *Biological Research*, Vol.36, n.1, pp. 67–88.
LLINÁS R., RIBARY U. (2001), "Consciousness and the brain. The thalamocortical dialogue in health and disease", in *Annals of the New York Academy of Sciences*, Vol. 92, n. 9, pp.166–175.
LLINÁS R., RIBARY U., JEANMONOD D., KRONBERG E., MITRA P. (1999), "Thalamocortical dysrhythmia: A neurological and neuropsychiatric syndrome characterized by magnetoencephalography" in *PNAS*, Vol.96, n.26, pp.15222-15227.
LUTZ A., LACHAUX J. P., MARTINERIE J., VARELA F. (2002), "Guiding the study of brain dynamics by using first-person data: Synchrony patterns correlate with ongoing conscious states during a simple visual task" in *PNAS USA*, Vol.99 n.3, pp. 1586–1591.
LUTZ A., THOMPSON E. (2003), "Neurophenomenology: Integrating subjective experience and brain dynamics in the neuroscience of consciousness" in *Journal of Consciousness Studies*, n. 10, pp. 31–52.
MATURANA H.R., VARELA F. (1980), *Autopoiesis and Cognition*, Kluwer, Dordrecht.
MATURANA H.R., VARELA F. (1987), *The tree of knowledge*, New Science Library, Boston.
MATURANA H., VARELA F. (1992), *The tree of knowledge: The biological roots of human understanding*, Shambhala, Boston.
MAURER D., MAURER C. (1988), *The world of the newborn*, Basic Books, NY.
MERLEAU-PONTY M. (2002), *Phenomenology of Perception*, Routledge, NY.
MESULAM M. M. (1999), "Spatial attention and neglect: Parietal, frontal and cingulate contributions to the mental representation and attentional targeting of salient extrapersonal events", in *Philosophical Transactions of the Royal Society London B: Biological Science*, Vol.354, n.1387, pp.13 25-1346.
PFEIFFER J., HOLLOWOOD T., HORT J., TAYLOR A. (2005), "Temporal Synchrony and Integration of Sub-threshold Taste and Smell Signals", in *Chemical Senses*, Vol.30, pp. 539-545.
RAMACHANDRAN V. S., HUBBARD E. (2003), "Hearing colors, tasting shapes", in *Scientific American*, May, pp. 52-59.
ROSENBERG G. (2004), *A Place for Consciousness: Probing the Deep Structure of the Natural World*, OUP, NY.
SMILEK D., DIXON M. (2002), "Towards a synergistic understanding of synaesthesia", in *Psyche*, n. 8.
SMILEK D., MOFFATT B. A., PASTERNAK J., WHITE B. N., DIXON M. J., MERIKLE P. M. (2002) "Synaesthesia: a case study of discordant monozygotic twins", in *Neurocase*, Vol. 8., pp 338-342.
THOMPSON E. (1995), "Colour vision, evolution, and perceptual content", in *Synthese*, Vol.104, pp. 1-32.
THOMPSON E. (2007), *Mind in Life: Biology, Phenomenology, and the Sciences of Mind*, Belknap Press, Cambridge, MA.
THOMPSON E., VARELA F. (2001), "Radical embodiment: Neural dynamics and consciousness" in *Trends in Cognitive Science*, Vol.5, n.10, pp. 418–425.
TURKEWITZ G., KENNY P. A. (1982), "Limitations on input as a basis for neural organization and perceptual development: A preliminary theoretical statement", in *Developmental Psychobiology*, Vol. 15, pp. 257-368.
VARELA F. (1996), "Neurophenomenology: A methodological remedy for the hard problem", in *Journal of Consciousness Studies*, Vol.3, n.4, pp. 330–349.
VARELA F., LACHAUX J.-P., RODRIGUEZ E., MARTINERIE J. (2001), "The brainweb: Phase synchronization and large-scale integration" in *Nature Reviews Neuroscience*, Vol.2, n.4, pp. 229-239.
VARELA F., SHEAR J. (1999), "First-person methodologies: Why, when and how" in *Journal of Consciousness Studies*, Vol.6, n.2-3, pp.1-14.
VARELA F., THOMPSON E., ROSCH E. (1991), *The Embodied Mind: Cognitive Science and Human Experience*, MIT Press, Cambridge, MA.
WARD J., SIMNER J. (2003), "Lexical-gustatory synaesthesia: linguistic and conceptual factors" in *Cognition*, Vol. 89, pp. 237-261.