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Neurodynamics and the mind

Włodzisław Duch

Abstract— **Is science of human experience, aimed at explaining phenomenology of mental events accessible through introspection, possible? What do we really known about ourselves and how do we know it? Psychology and neural sciences have turned away from such questions and experimentally oriented philosophers discovered formidable obstacles in attempts to answer even simple questions about the nature of conscious experience. To talk in a meaningful way about subjective mental processes a new level of description is needed, resulting from neurodynamics but connected to inner experience. Visualization of neurodynamics may lead to geometrical, continuous models of mental events. It should allow to view brains and artificial cognitive systems form mental perspective.**

I. INTRODUCTION

PSYCHOLOGY and cognitive science have largely given up on the concept of mind, focusing on specific experiments that elucidate brain functions. The word *psychology* appeared in the middle of 17th century, as a combination of *psyche* (breath, spirit, soul) and *logia* (study of), and acquired clear meaning as "the study of the mind" in *Psychologia empirica* (1732) by G. Wolff. Behaviorism and later cognitive science turned away from introspection and subjective perspective. The new science of consciousness tries to replace mental perspective with brain activity based on neural correlates of conscious experience. The philosophical position known as *eliminative materialism* [1] claims that folk psychology (common-sense understanding of the mind) is false and many poorly defined concepts have no coherent neural basis. Shoving away questions based on naive understanding of the mind as non-scientific brings focus on brain activity that can be objectively measured. However, it has not led to understanding of mental perspective in a deeper way. Folk psychology description of mental events may be a wrong conceptualization of brain states, but it plays an important role in communication and has great influence on human decisions.

Without models of mental processes that provide specific language reflecting underlying neurodynamics and at the same time connecting them to the psychological descriptions the mind-body problem will always look mysterious [2]. Many problems in the philosophy of mind are direct result of the lack of proper level of description. The next section contains general discussion of some difficulties facing the science of human experience and the third section more detailed description of one particular problem, imagery agnosia. Our thinking is dominated by vision and visual metaphors, therefore attempts to create dynamic geometrical models of cognition are reviewed in section four. The fifth section links geometric models to neurodynamics and shows how they help us to learn a few things about ourselves.

II. WHAT DO WE KNOW ABOUT OURSELVES

How can we speak about the mind, subjective inner experience, and what is there to speak about? Folk psychology conceptualization of the inner experience does not map uniquely on the brain states. At the beginning of 20th century psychology tried to be the science of human experience, but failed to create a comprehensible theory of mind. The efforts of early experimental psychologists to use "systematic or experimental introspection" for the study of consciousness at the beginning of the 20th century did not succeed. Paris (Binet), Cornell (Titchener) and the Würzburg Schools (Mayer, Orth, Külpe) worked on integration of the first and second-person data with objective measurements, training people in systematic introspections (Titchener created a 1600 pages long manual for experimental psychology). Color experience can vary along 3 dimensions (hue, saturation and brightness, although other color models may be used), can similar characterization be done to describe other types of experience? A few psychophysical laws have been discovered, but quantification of experience proved to be difficult. Consensus could not be reached on dimensions characterizing emotions, or existence of "imageless thought" [3].

As a result psychology became dominated for a long time by behaviorist methods, banning the scientific study of subjective experience for many decades. Behaviorism had no ambitions to explain human experience, focusing on a seemingly simpler task, explanation of behavior, without abstract constructs such as the mind or consciousness. Belief that thought is a rational conscious activity, with access to all mental processes, working in a similar way in all people, created a framework in which diversity of results based on introspection could not be accommodated. Each brain is unique, solving the same task using different strategies, and this creates a big problem for all statistically-oriented experimental approaches that average over many uncontrolled factors. Cognitive functionalism and neuroimaging techniques, dominating today, suffer from similar problems to the introspectionist approach. Mere localization of brain functions is not yet an explanation of mental function. Practically all major brain areas and structures have been implicated in a large number of functions, depending on the context [4]. Understanding covert processes has proved to be much harder than originally expected.

Empirically inclined philosophers tried to explain the first-person experience using systematic reflection to study

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Włodzisław Duch is with the Department of Informatics, Nicolaus Copernicus University (email: wduch@is.umk.pl), and with the School of Computer Science, Nanyang Technological University, Singapore.

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phenomena, or acts of consciousness. The phenomenology school became quickly split into the transcendental approach of Edmund Husserl, and more existentially grounded analysis of the ways of being of Martin Heidegger, Maurice Merleau-Ponty and others. Some of these ideas led Francisco Varela and his co-workers to the development of neurophenomenology and attempts at "modernizing introspection". Although their book on the pragmatics of experiencing [5] contains a lot of methodological remarks, connections to the ancient wisdom traditions that introduced awareness increasing practices, it does not give any insights or new concepts that could be used for description of mental processes. Mindfulness training is important in affective sciences [6], but noone has yet demonstrated that it is a way to more accurate results than systematic introspection in the past. Emphasis on the ecological approach to perception [7] and the importance of embodiment and action for cognition is responsible for the trend in cognitive science towards embodiment and enactivism, dominating now in developmental robotics. Enactivists criticize classical representational views of the mind, focusing on the dynamic perception-action cycle, tuning the organisms to the affordances of the environment.

In their book "Describing Inner Experience? Proponent Meets Skeptic" Russell Hurlburt and Eric Schwitzgebel [8] tried to answer the question "Can inner experience be accurately apprehended and faithfully described?" in an empirical way. A person trying to describe details of her mental states at random moments (prompted by a beeper), despite numerous clarifying questions, provided vague, frequently confusing and at times contradictory descriptions. People are not the best judges of their own phenomenology, and may be confused or mistaken about their own experience. In the book "Perplexities of Consciousness" Eric Schwitzgebel [3] discusses a wide range of mental phenomena arguing that we are unable to describe and understand our own stream of conscious experience. Numerous examples show that frequently we are not able to determine character of our own experiences related to dreams, imagery, peripheral vision, perspective and visual illusions, use of echolocation, or emotional experiences. More experiments with beepers with larger groups of people showed that even a simple distinction between sparse and abundant experience, between marginal and dominating unconscious perception, is impossible to make. For a long time no-one has tried seriously to describe inner experiences in some details. This may be possible only in a few simple situations, like binocular rivalry.

Apparently beliefs about ourselves may not only influence, but completely determine interpretation of our mental states. As with the scientific observations that are theory-laden and cannot be interpreted without theoretical framework our own internal phenomenology seems also to depend on our theory of mind [9]. This is indeed surprising and goes contrary to the common belief that we cannot be mistaken about our own experience. Why it could be hard to reach a judgment about what is in our mind, to be clear about how things appear to us? What can we really know about ourselves, and how do we know it?

Concepts serve as labels distinguishing classes of brain states resulting from perception of objects, their properties, sensory stimulations, emotional states, and more abstract ideas such as color, self and mind. To understand why people make specific comments about their experience we need to do 3 things: 1) categorize quasi-stable brain states, 2) understand the dynamics of their succession, and 3) understand what kind of comments may be generated about this process. Categories of quasi-stable brain states that tend to repeat themselves often are labeled by concepts that facilitate communication. A good part of this process is innate: hearing phonemes, seeing shapes, colors and movement is learned in an unsupervised manner if sufficient stimulation is provided during the development. Another part, responsible for the phenomenology of internal brain states has to be learned. Linking experience with language requires supervision, has influence on categorization and brain dynamics, and thus changes inner perception.

Literature on cross-cultural color perception [10] shows that categorization of colors in different cultures significantly differ, and this may influence perceptual learning. Learning to distinguish amaranth from alizarin and amber color on an artist's palette requires precise categorization of states of the visual system. If we learn to pay attention to the subtle differences between these colors, and if we learn their names, we will be able to describe our inner experience with greater precision. In some cultures spatial orientation is always given in absolute terms (east-west, like in sea navigation) rather than egocentric coordinates (left-right); other languages require always specification of gender and lead to association of more feminine or masculine properties with neutral objects; still other languages always enforce giving specification where exactly the information comes from: direct observation, inference, conjecture, hearsay etc [11]. Language habits change brain states [12] and thus the way mental states are described as well as how they are experienced.

Schwizgebel [3] reviews research on experiencing color in dreams and finds it very confusing, unable himself to decide whether he does experience color in dreams or not. In discussion of human echolocation and other subjects paying attention to weak signals, and training to analyze them, changes brain dynamics. What used to be fuzzy and hard to categorize becomes more precise and easier to distinguish. Initially I may not be sure of my own experience, because brain activations that support it are weak and have a large variance, so I am not able to recognize them in a reliable way. Learning will make experience better defined, with presumably stronger brain activations with less variance, although it may be still hard to see it with the current brain imaging techniques due to the context dependence. However, to learn new phenomenology I need to know what to look for in my experience, where attention should be focused. In the example of a blind men convinced that information about obstacles is in the facial pressure [3] attempt to link his tactile impressions with obstacle avoidance may not be successful, but if his attention is directed towards auditory stimuli they may quickly improve. Learning has always been a problem for systematic introspection in the first psychological laboratories, as it tends to create descriptions that converge on the expected ones after a large number of trials.

To describe experience one needs to categorize or discretize brain states, assigning labels to a dynamic distribution of brain activations. Experience is always much richer than language can express, as it is impossible to have enough symbols for all possible brain activations. Common concepts are useful for communication of important distinctions between mental states. Specialized vocabulary to describe detailed phenomenology of brain states does not exist and would perhaps be too idiosyncratic to be useful. Verbal statements are comments on the successive brain states or categories of experience that transmit socially relevant information. Communication is possible if there is an approximate correspondence between concepts and mental experience (and brain states) that they point to. Brains of babies do not support all the mental states that adults have, so many concepts must elude them. Conceptualization of brain states in different cultures and languages may be dissimilar, although as a whole it covers similar space of possible cognitive and affective states. Matching semantic maps between different languages is a non-trivial task [13].

Brain activations in states of consciousness that are normally not involved in communication, like dream states, meditative states, hypnotic, somnabulic, or hallucinatory experiences are rather different than normal conscious mental states in which we have learned to communicate. In such unusual states it may not be possible to establish correspondence with the symbols used to characterize brain states during normal perception. Visual experience engages coordinated activity of ventral and dorsal pathways in the visual stream; in macaque monkey there are over 30 visually responsive cortical areas. If something goes wrong with the top-down or bottom-up information flow all kinds of visual agnosia may arise. While classical apperceptive, color or associative visual agnosias due to the bottom-up stream impairment are well recognised, top-down impairments may lead to what I have called *imagery agnosia* [14], that have not yet been investigated by neuropsychology. They have quite specific phenomenology that is hard to describe using standard language: the words that we use do not label these experiences with sufficient accuracy, have little meaning for people who cannot experience them, as they do not map well categories of brain states from impaired to normal brains.

III. IMAGERY AGNOSIA

Two important aspects that can help clarify some of the confusion surrounding introspection are: first, lack of appreciation how much inner experience may be different for different people, and second, how can the continuous brain states be described using discrete symbols. The second question is discussed in the next section. A good example of the first problem is what I have called an "imagery agnosia" [14].

Agnosia is usually associated with the bottom-up processing stream, inability to extract relevant information from the sensory data. It is commonly agreed that top-down processes help to establish conscious percepts [15], [16]. Imagery of visual, auditory or other sensory information needs sensory cortex to re-create conscious qualia in proper modalities. Usually top-down processes are sufficiently strong to activate sensory cortices, establishing resonant states between associative and primary sensory brain areas [17]. Feedforward and feedback connections differ in respect to the type of cells and the types of neurotransmitters and are very complex. In the V1 area of macaque over 40 types of interneurons alone have been described. Feedback connections in most brains are sufficiently strong to create activation needed to form a vivid percept, but what happens if they are too weak?

This general condition may be called "imagery agnosia", as subjects may show all kinds of symptoms typical for agnosia when required to perform some tasks based on imagery. Problems with visual imagination describes as dim, pale and non-existing may probably be linked to the strength of the up-and-down stream resonant states [16]. Noisy, fluctuating activations that do not form quasi-stable states cannot be uniquely categorized, so in this realm experience remains ambiguous and reports are confusing, as discussed by Schwitzgebel [3].

In auditory imagery agnosia the ability to consciously imagine pitch and timbre of sounds is missing. People with vivid auditory imagery show Evoked Response Potentials (ERPs) in the auditory cortex for sounds that are missing from well-known melody as if they have heard them, filling in the missing sounds using their imagination. It is conjectured that people who cannot imagine sounds will show no auditory ERP response, and that such responses will be correlated with the vividness of auditory imagery questionnaire, as they are in case of vision. The only way that someone with auditory imagery may know that there is a melody in his/her head is by humming or playing it on an instrument.

Faw [18] has pointed out that conflicting intuitions on imagery may be based on different abilities. He himself has no visual imagery, a claim that has been met with incredulity by his colleagues in psychology and philosophy. The existence of imagery agnosia is still controversial in neuropsychology and may be directly linked to the "imageless thought" controversy of the early introspectionist debate [3] and the whole philosophical and psychological tradition linking thought with images. I have personally met quite a few people who claim not to have visual imagery and I am certain that I also do not have it. There is nothing uncertain to it: shapes and colors do not appear in my imagination, I have no idea how people are dressed or what is the color of my wife's coat when I do not see it. I cannot draw from memory (but drawing from nature is not a problem). Moreover, it is not just the lack of visual imagery, but also of imagery in other sensory modalities, including auditory, tactile and gustatory sensations. Little statistical data on how many people are visual non-imagers have been collected since Francis Galton's 1880 paper! Faw [18] estimates that only 2-5% of people are not able to form visual images. It is safe to say that not much is known about individual differences in this respect [3].

The Vividness of Visual Imagery Questionnaire (VVIQ) [19], [20] measures the ability to re-create visual experiences. Score of subjective evaluation of the vividness of experience calculated from this questionnaire is strongly correlated with the activity of primary visual cortex. Questionnaires similar to the VVIQ have not yet been developed for evaluation of vividness of experience in other sensory modalities, although Faw [18] has made some simple surveys asking people about mental sounds (2% claimed no image) and recalling the song (12% could not hear it but could hum). Neuropsychologists created good tests for amusia, such as the Montreal Battery of Evaluation of Amusia (MBEA) [21], but the model of processing sounds employed in this test contains only feedforward connections and has no place for imagery. Congenital amusia or tone deafness affects only about 4% of the population not capable of fine-grained pitch discrimination. Auditory imagery agnosia is quite different and is not connected with amusia (presumably bottom-up auditory processing channel), but rather with the inability to imagine sounds (presumably top-down activation of auditory cortex).

To my best knowledge no-one has described phenomenology of auditory imagery agnosia. I have conducted informal experiment to elucidate it, going through audiometric tests first that found my hearing to be quite normal. Although I always had a great appreciation for all kinds of music and had some piano lessons in the school my progress has been slow. Associations between sounds and actions (pressing the piano keys) could not be formed because I do not know what sound will be produced when the key is hit. Repeating the melody is always a matter of trial and error; it is easy to hear that the sound is wrong but impossible to guess which sound will be right. Rote learning after many repetitions allows me for formation of some simple motor sequences. However, it is due to the procedural rather than declarative memory, and results do not generalize to other instruments. My recognition memory works quite fine, with the ability to recognize hundreds of musical themes and songs. I could learn musical notation and play various flutes and an electronic wind instrument (EWI) from written scores without much trouble.

After some years of playing recorder and 3 years of playing EWI I also learned to improvise, avoiding the use of out of scale notes on wind instruments. Although I have to rely on musical score to play well-known tunes, I can add improvised twists to what I am playing, invent new melodies and show some musical creativity. Evidently at the higher cognitive level my brain was able to internalize a lot of musical knowledge that I am consciously not aware of. Each action is a step in the dark, without knowing the consequences. I feel like a listener, surprising myself, with seemingly no conscious influence on what I am playing. This experience can be compared to blindsight [22] where after a period of training one develops a feeling where to make a step, although this is not accompanied by visual experience. With auditory agnosia trying to play a piece of music is similar to maneuvering blindly in the auditory space, without the ability to imagine what will happen when you hit particular key. I have frequently tried to imagine the pitch or timbre of an instrument, but without success.

These observations have wider implications for understanding how do we know ourselves. There is clearly some imagery in my head that I cannot see or hear. Like most other people I am able to dream and daydream, although without sensory aspects associated with imagined situations. I seem to weakly feel the actions, movements, to know what is it about, know who is involved and what is happening, yet all this is on some abstract level. Perhaps it is worthwhile to distinguish between more abstract and sensory-based imagery. On a rare occasions while falling asleep and in hypnagogic state I have heard a brief vivid sound. Sensory deprivation in isolation tanks did not induce any auditory or visual hallucination. The use of aspirin may prompt silent colorful dreams, presumably by increasing blood flow during sleep.

A good part of what I know about myself comes from observation of my actions in the world and predicting these actions to create a model of my behavior. Hearing myself humming I discover that there is a melody, or rather recognition of some processes that do not have sensory qualities, going on in my head. Without internal feedback the only way to learn about this process is to produce music and hear it. People with imagery amusia are not much more privileged to have conscious insight into their own brains then external observers. Sometimes the only way to know what goes on in my brain is to act it out. This situation may happen more often than we are willing to admit, with a whole range of problems related to the inability of consciously interpreting our own brain states, and the need to express and recognize them through bodily actions. Verbal thinking allows for recognition of some other processes, although words that I am able to recognize internally do not have any sensory aspect, pitch, timbre nor gender. Perhaps imagery agnosia may actually help in abstract thinking, as neural activity is not dispersed into sensory cortices. It would be quite interesting to find out what percentage of mathematicians or theoretical physicists have a similar condition (subtle differences between people working in different branches of science, for example geometry and algebra, may probably be found). Better understanding of these issues may have far reaching implications for education, assessment of talent, and correlation of brain activity with conscious experiences.

Because the vividness of imagery for sounds, tastes or tactile experiences differs among people it may be dangerous to average results of brain imaging for different people. Imagery should be positively correlated with the strength of top-down connections activating sensory cortices by signals from brain structures responsible for episodic memory. In extreme cases people may have as vivid imagination as during actual episodes, mixing their imagination with reality, but if the feedback connections are weak they may not be able to imagine sensory experiences at all. A relatively small, but significant number of people are not able to recall any visual details if they are not specifically instructed to pay attention to them. To remember simple features (like the color and type of dress of their partner) they have to (verbally) describe it to themselves. This distinction between "verbalizers vs. visualizers" is used in education and consumer research [23], with psychometric measures of imagery ability, processing style and daydreaming/fantasy content and frequency.

In dreams only a subset of visual areas may be activated, leading to kind of visual experience that is quite hard to describe. For example, activation of the inferior temporal gyrus and MT areas without stronger activation of V1-V4 areas may give the feeling of object motion without shape or color, or of knowing that some people are acting without visualizing them. This is frequently my own feeling when I think about a movie, recalling the action and the people involved without real visual experience. This phenomenon can be described by classical signal detection theory [24].

One way to test the conjecture that top-down activations due to imagery are simply too weak to establish brain states that could be uniquely categorized and lead to well defined percepts is by using stochastic resonance effects. For low-contrast or noisy images adding noise of different intensity and temporal characteristics may improve the quality of perceived images [25]. The wrong type of noise may create an opposite, masking effect. In the auditory perception stochastic resonance is easily overshadowed by masking [26]. Stochastic resonance has been demonstrated in other sensory modalities and even in associative processes in creative thinking [27]. Of particular interest here is the crossmodal stochastic resonance created by auditory white noise at about 70 dB [28] that increases sensitivity to visual, tactile and other percepts in most subjects. I have tried to induce auditory or visual imagery in this way, and although it may require more attempts to find the best noise parameters the method seems to be promising, although the images and sounds were dim, unstable, struggling to establish themselves but falling after a few moments. The use of transcranial magnetic stimulation is also worth investigating.

Schwitzgabel concludes that only a compelling theory of consciousness could resolve the problems of understanding phenomenology. To model the mind we must know its content and this seems to be very elusive. Neural models may explain why it is so and why these disputes are so hard to resolve, without making commitments on the distribution of consciousness. This explanation is now hidden in equations and models, and it needs to be shown for better understanding of mind processes. A step in this direction is made below.

IV. DYNAMIC COGNITION

How can the continuous brain states be described using discrete symbols? How should we speak of mental events? Establishing rules correlated with neural states [29] may not be quite satisfactory. Dynamical approach to cognition has been the dream of psychologists for a long time. Kurt Lewin inspired by physics already in 1938 defined a framework in which psychological forces operated on mental states in appropriate spaces [30]. His force field analysis has been applied to social situations, process and change management, and organizational development. George Kelly in his psychology of personal constructs [31] proposed geometrical approach to personality, based on bipolar categories. He introduced role repertory grids, that may be presented as a graphical model, or as a matrix of connections and constraints between objects and their features. Constructs are combinations of features that allow for categorization of objects, for example personalities that may be characterized by various features. Some experts proposed that his approach based on the geometry of psychological spaces should be used as a foundation for cognitive modeling [32]. Principle components showing directions with the largest variance may be used to inspect data distribution in this space.

Roger Shepard in a celebrated paper "Towards a universal law of generalization for psychological science" [33], wrote: *What is required is not more data or more refined data but a different conception of the problem.* His dream was to have a theory of mind akin to physics, where after transformation to a proper space natural invariances will arise, as for example they do in a very elegant way in Riemannian spaces. Brains adapted to physical environment should show some perceptual-cognitive universals reflecting properties of the world [34]. Several examples of such laws have been discussed in the special issue of *Behavioral and Brain Sciences* journal [35]. The metric appropriate for modeling spaces in perceptual and conceptual domains should be based on apparent similarity or dissimilarity. In this special issue Shimon Edelman proposed to use "neural spaces" that internalize in the brain various aspects of the structure of the world, a move from abstract description of perception at the psychophysics level towards neural level [36]. Unfortunately this idea never became popular and also remain at the high level of abstraction.

Several other attempts have been made towards creation of a language in which mental processes could be described. The book *Mind as motion* [37] introduced dynamical systems approach to cognitive science, that has also been used by developmental psychologists [38], and it had important (although limited) impact on thinking about temporal dynamics of mental processes, moving away from discrete, symbolic representations towards "continuity of mind", as Spivey has called it [39]. Symbolic dynamics that he used to describe this continuity has actually led him back to discrete representation but it can be amended [40]. Peter Gärdenfors introduced conceptual spaces as a framework for modeling representations [41], using spaces based on quality (for example, perceptual qualities), and phenomenal dimensions that could be inferred from perceived similarities using multidimensional scaling, as Shepard has done. This approach introduces geometry of cognitive representations and connections between perceptual and linguistic representations as an alternative to symbolic and connectionist models. Although the “Conceptual Spaces" book has been quite popular it is hard to find examples of mental processes explained in this language in learning, concept formation or language understanding. Mental models have been created with the hope of explaining language, inference and consciousness [42] but ended up with rather simple symbolic models that bear no relation to the brain functions.

In linguistics Gilles Fauconnier introduced “mental spaces” [43] and later conceptual blending (or integration) as a general theory of cognition [44]. Jeffrey Elman looked at language from the dynamical system point of view, treating linguistic representations as regions in the state space and grammatical rules as restrictions on the possible trajectories in this space (chap. 8 in [37]), leading to attractor dynamics. Simple recurrent network served as a model of such system predicting next word in a sentence, and the activity of the hidden units displayed in the principal component coordinates showed the dynamics. In psycholinguistics latent semantic analysis theory [45] also allows for visual representations of lexical concepts. In principle distance relations between these components should be similar to distances between activations of the brain areas coding concepts, as shown in a simple network model by James McClelland and Timothy Rogers [46]. Functional magnetic resonance image of the brain activity associated with the meanings of words can be predicted [47].

This brief overview shows that there have been many efforts to create dynamical models of language. Already David Marr wrote about the probabilistic landscape [48] in which probability density functions over a set of features should have peaks around stimuli associated with features of objects that can be recognized. This idea has been implemented using neurofuzzy networks [49], but it simply offers a descriptive model using networks that estimate probability density, for example radial basis function networks or separable basis function networks [50] with nodes that can be interpreted as products of fuzzy membership functions. Learning on examples such networks built approximation to the probabilistic landscape that Marr has imagined, and can combine knowledge from partial observations in solving more complex problems [51].

More interesting question is how to link neural dynamics with conceptual and mental spaces. This could indeed introduce a new level of description of mental processes that in principle could be linked to phenomenological descriptions – if we only could create them – and to neural dynamics. The language of dynamical systems could then be used to talk about mental events as a rough description of most salient neurodynamical events, that is quasi-stable, possibly attractor states of activity. In continuous neural models one can talk about probability distributions of activity over larger brain areas, including bubbles of activity [52]. Such language could be used to discuss masking phenomena, attention blink, categorization, learning, internal reporting, spontaneous thoughts, associative thinking and many other processes.

V. MIND FROM INNER PERSPECTIVE

The failure to capture phenomenology of conscious experience described in Sec. 2 shows that it may not be possible to define internal quality dimensions for conceptual spaces [41] or to define features that describe concepts in mental spaces and allow for conceptual blending [44]. Formal transformation from the space of measured brain activity to some mind space based on dimensions that can be related to the inner experience, as formulated in [53], is thus not feasible. However, it may still be possible to estimate similarity of new brain activity to memorized brain states. This leads to internal representations based on dimensions that measure complex qualitative similarity of the whole objects and their parts or aspects at different levels of organization, rather than dimensions based on properties of individual signal streams.

Kernel methods may be relevant for category learning in biological systems, but perhaps not in the standard formulation used in support vector machines (SVM), as it has been proposed in [54]. Kernel features based on similarity may be mixed with simple projections of signals, localized projections and other transformations [55] achieving even better results than SVMs that are restricted only to the kernel space. Such transformations may be implemented as functions of microcircuits that are present in cortical minicolumns, or at a higher processing level, as functions of larger neural assemblies. In effect initial layers of signal transformation approximate a liquid state machine [56]. With great diversity of microcircuits a lot of information is generated, and relevant chunks are used as features by simple Hebbian learning of weights in the output layer. In such model plasticity of the basic feature detectors receiving the incoming signals may be quite low, yet fast correlation-based learning is still possible. Similarity is calculated at higher levels of processing, and in effect dimensions of conceptual spaces may have mixed character, some coming from initial reactions of sensory cortices to incoming signals and some coming from reactions of higher brain areas. Not all these signals are sufficiently strong to realize their presence in inner experience, and they may be combined (blended) in so many different ways that only rough narrative description reporting on the mental content will be possible.

The second aspect that makes attempts to create geometrical model of mind quite difficult is the naive view of probabilistic landscape that Marr and other experts imagined. The landscape of accessible states is much more dynamic, depends on the recent activity of neurons that at a given point in time determine the set of potentially accessible states in mind space. We have studied neural synchronization and attention shifts, trying to correlate biophysical properties of neurons and network connectivity with the dwell time of neurodynamics in attractor basins [57]. To this aim several models of normal functions have been implemented using Emergent simulator [58]. For example, using the 3-way dyslexia model (orthography, phonology and semantic layers connected with each other through hidden layers, Fig. 1) trained on 20 abstract and 20 concrete words trajectories of the semantic layer (140 units) showing how it settles in attractor basin for each word have been observed. To compare details of this process we have used visualization based on fuzzy symbolic dynamics [40]. Dimensions used for such display (Fig. 1) are in this case based on similarity to 2 or 3 general prototypes. The system starts with no activation and after the orthographic layer is prompted goes into a transition state and reaches the basin of attractor for a given word, exploring it due to a small synaptic noise. The division between abstract and concrete words is quite clear, with the abstract words reaching their basins faster (this does not mean that reaction time to distinguish this state from non-words will be faster than from words). Priming by many unrelated words may in such system may bias it into attractor basin that shares most activations with the primes; the system has then tendency to go into this attractor basin spontaneously or after prompting it with meaningless input (adding energy to the system). This mechanism may be used for various manipulations.

After convergence to the attractor basin the system may spontaneously evolve (Fig. 1, right) making transitions to other basins. The speed of this evolution measured by the dwell time, or by the average time between transitions, depends on the noise in the system, but even more strongly on neural fatigue or accommodation, controlled in the model by the leak ion channel conductivity. Fig. 1 (right) shows the probabilistic landscape once Marr thought of, where a word flag has been used to start the dynamics, and the system wanders around real and imaginary words (spurious basins of attraction). However, the main reason why this system jumps from one attractor basin to another is due to the accommodation effect. Basins of attraction simply cease to exist and are not accessible for some times, so static pictures are deceiving. After a period of strong concentration on one subject completely unrelated thoughts may arise. Neural systems, even with clamped input, may cycle their activity among different attractor basins, returning back to the first basin after neurons will rest.

Despite the diversity and complexity of symptoms in Autism Spectrum Disorders (ASD) and ADHD it is quite likely that a whole spectrum of mental problems may arise due to the abnormal synchronization of neurons in the brain. This should manifest itself in neurodynamics as basins of attraction that trap brain states in different ways. If synchronization is too strong (low accommodation) most basins of attraction will enslave brain dynamics for a long time, therefore once attention is focused it cannot be easily disengaged. In visual areas this leads to a fixed gaze, in auditory perception fixation on continuous sounds, and in the motor areas this leads to repetitive movements and compulsive-like behavior. Increased noise in the system (fever) should decrease the symptoms. Weak synchronization leads to fast jumps from one basin to another without the ability to focus on anything.

VI. CONCLUSIONS

Many mysterious aspects of human experience look much less mysterious if approached from the neural modeling perspective. Review of philosophical and psychological attempts to create phenomenology of the human experience showed essential failure of introspection to provide first person perspective. Schwitzgebel [3] discovered many situations in which it even seems impossible to characterize mental content. I have added to his examples personal description of imagery agnosia, a new area that neuropsychology has so far ignored. The lack of feedback connections from associative brain areas to the sensory cortices is probably responsible for most of these difficulties, and enhancing imagery using stochastic resonance has been proposed to test this conjecture. A dynamic approach to cognition has tried to avoid quantized, logical symbolic description of mental state by introducing various conceptual spaces, but so far these efforts have created new language that could link mental and neural events. First, internal quality dimensions are not easy to define, they may be related to similarity to complex states rather than analysis of separate sensory signals. Second, the probabilistic landscape of mental spaces may be truly dynamic, quickly changing in time. Visualization of trajectories for words in the semantic space may help to construct models of illustrating memetic processes.

Science of human experience requires continuity of mind [39] and visualization of neurodynamics of biologically motivated neural networks may be the way to a new dynamical language that can be at its foundation.

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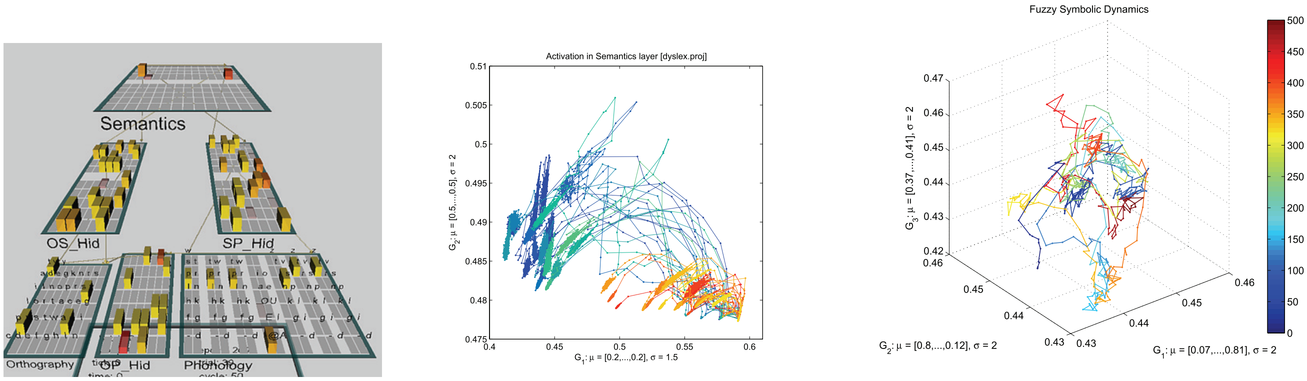

Fig. 1

LEFT: MODEL OF READING IN EMERGENT; MIDDLE: BASINS OF ATTRACTORS FOR 40 WORDS, RIGHT: TRAJECTORY OF SEMANTIC LAYER AFTER PROMPT WITH THE "FLAG" WORD IN FSD MAPPING.

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