ENERGY AND EXPECTATION

The Dynamics of Living Consciousness

MICHAEL TRESTMAN

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ABSTRACT

Jablonka and Ginsburg (2022) theorize that a) consciousness is closely tied to goal-directed behavior and an open-ended capacity for learning and adaptation driven by exploration-and-stabilization dynamics; and b) consciousness has this essential dynamical nature due to its emergence in evolution from the spontaneous exploration-and-stabilization dynamics of animal life, which the authors term vivaciousness. I explore these two claims with relation to two features of experience that are of clear importance to goal-directed behavior both phenomenologically and biologically 1) the role of probabilistic expectation, and 2) the role of available energy. Applying Jablonka and Ginsburg's framework, I argue that these two features are substantive and potentially universal examples of consciousness being shaped by biology.

I BACKGROUND

Jablonka and Ginsburg (2022) reconceptualize life and consciousness as teleological modes of being: distinct patterns of dynamical organization characterized by distinctive domains of goal-directed activity. Their analysis beings from a consensus- based, attribute-cluster definition of consciousness. This cluster includes hedonic value (pleasures, pains, urges, fears, cravings, revulsions, etc.), which drives distinctive types of (hedonically motivated) goal-directed behavior, including the advanced cluster of learning abilities they jointly label "unlimited associative learning" (UAL). Consciousness also includes 'temporal depth', i.e. the temporal content of conscious experience typically exceeds the duration over which that experience unfolds (especially at the limit of 'briefest possible moment of experience'), by including an anticipatory awareness of upcoming experience based on a rolling window of short term memory, which is operationalized as learning based on information spread over time (in computational terms, predictive relationships among data)—also required for UAL. Because it depends on distinctive computational features of consciousness, UAL is therefore argued to be a taxonomic indicator of consciousness, on the basis of which Jablonka and Ginsburg justify their evolutionary origin scenario for consciousness in the arhtropod, vertebrate and mollusk lineages. See Trestman (2016) for a parallel argument in support of the same origin scenario. The conceptual inter-relation of temporality, hedonic value, learning, and goal-directedness has been of interest from many theoretical perspectives since ancient times, for example in the Buddhist theory of the kleshas, or in the radical Stoic view that material comforts are irrelevant to true human well-being. It has also driven the development of theoretical paradigms in philosophy and the sciences of life and mind, across the 20th and into the 21st century. For example, at the crux of the behaviorism/cognitivism debate in American psychology, Tolman argued that psychology could not understand animal learning without taking into account the purposive cognitive process, choice, by which a specific animal, in a specific situation, evaluates concrete possible courses of action and their anticipated consequences (1938). Kull (2022) calls the fundamental moment of choice, in which a subject can recognize multiple alternative possibilities in virtue of feeling simultaneously, incompatible, urges to action, "the fundamental point that connects phenomenology, semiotics and physiology". From a semiotic perspective, learning is not just increase of information, but growth of the network of meaning- bearing signs through which an agent relates to their environment; learning enables choice, increasing the 'semiotic freedom' of a situated agent, enabling them to perceive and enact a broader repertoire of affordances, and more successfully model and navigate their situations (Campbell, Olteanu, and Kull, 2019). For conscious creatures, learning is a change in behavior as well as an experiential and semiotic process. It is the discovery of meaning in the lived environment, and the growth of competences to meaningfully act, choosing the shape of the future through ones actions. In biocomputational or biocybernetic terms, learning is improvement in being able to predict the evolution of situations, and in particular to solve the coupled prediction/control problem of moving the body so as to achieve a goal outcome or maintain a set of measured variables within goal ranges. How are these aspects related? In this paper I shall first argue that understanding goal-directedness in terms of maximizing action-conditionalized subjective probability can help to conceptually bridge the behavioristic, phenomenological, and semiotic aspects of learning highlighted by these claims. Second, I argue that Husserl's phenomenological theory of the core temporalizing structure of consciousness clarifies certain of Jablonka and Ginsburg's central claims. In combination, these tools afford an elucidation, from the perspective I would call 'biocomputational phenomenology', of the semiotic concept that learning is not merely the acquisition of information, but the growth of a capacity to make meaningful use of information through choice (Campbell, Olteanu, and Kull, 2019; Kull, 2022). Finally, combining the neo-Husserlian model with Jablonka and Ginsburg's focus on exploration-and- stabilization as a fundamental dynamic of life and consciousness, I explore the largely neglected energetic dimension of experience. This has potentially broad significance for the evolution of autonomic regulation—which I would define broadly as the predictive regulation of metabolic production and physiological circulation of ready-to-use energetic fuel by a creature's assessment of the current situation's requirements for action. Most often, this is related to assessments of danger and preparation for defensive behavior, but also to affordances for other ecologically salient energetic activities, such as mating, competing for resources, or pursuing challenging prey. This capacity appears to have evolved independently in vertebrates, arthropods and mollusks, which seems to bolster Jablonka and Ginsburg's evolutionary narrative in a way not considered by the authors.

II GOAL-DIRECTEDNESS AND EXPECTATION

Jablonka and Ginsburg's discussion of goal-directedness, agency, and plasticity highlights the pattern of exploration-and- stabilization, wherein alternative behaviors are attempted in sequence before one of them (normally the 'best', most effective, accurate, or efficient) is adopted. Tolman (1932) used the technical term 'docility' for this pattern of sequential experimentation and selection of the easiest, least energetically taxing, or most successful option, to "imply and define, objectively, purposes and cognition, which are immanent in behavior". I understand goal-directedness in slightly broader terms, with exploration-and-stabilization/docility being a special case, albeit a uniquely important one. I define a goal in the dynamical sense as a specific result that a complex system with a repertoire of different behavior will tend to bring about across a range of different contextual conditions by matching behavior to context. This propensity to match means to conditions thus converging on a particular result makes the point of convergence into a goal for the system (Trestman 2010, 2012). In probabilistic terms, an agent's behavior is directed at a goal when the agent does whatever seems to them most likely to bring it about. More precisely, we can say that the behavior of a system or 'agent' A, is directed at a goal G across a set C of possible situational contexts, just in case for any specific situation in that set, A's behavioral response maximizes the conditional probability of G, or in other words, there is no alternative behavior with a higher conditional probability of G (Trestman, 2022).

Formally, A's behavior is directed at goal G across set C of possible situational contexts (c1,c2,c3,..) just in case:

> There exists a goal-directed behavioral responsivity function R, from contexts in C to behaviors $(b_1, b_2, b_3, \ldots)$ in A's repertoire B, such that:
>
> > for any specific situation c_x in C,
> > if $b_x = R(c_x)$, then there is no behavioral alternative b_z in B such that:
> > $$P(G \mid b_z \cap c_x) > P(G \mid b_x \cap c_x)$$

By framing goal-directedness in terms of convergent maximization of subjective conditional probability, we can think of sequential experimentation-and-stabilization as a general heuristic for tuning conditional probabilities of success (or conditional probability distributions of a set of metrics of success) for alternative means of attempting a goal, via broadly Bayesian heuristics. Goal-directed behavior is the propensity to ensure a goal across a variety of contexts by matching means to context; it becomes more effective/efficient as a) the agent's ability to anticipate the consequences of possible actions improves through observation, and b) new possible actions, discovered through spontaneous, experimental/exploratory behavior, are added to the repertoire of behaviors for which the agent can form subjective conditional probability distributions. Orientation toward goals must be co-constituted with an experiential understanding of one's world and capacities for action. "Kinesthetic/kinetic discoveries are the cornerstone of agency." (Sheets-Johnstone 2016) The general schema of exploration-and-stabilization is itself a hierarchical goal-directed behavior, implementing the following response function: If the best known, available possible behavioral tactic in the repertoire is reasonably expected to succeed, attempt it; if not, experiment/explore. This maximizes the success-odds of the higher-order goal of maximizing the success- odds of whatever lower-order goal to which it is applied, and can be seen as a universal goal-directed strategy for increasing knowledge and avoiding becoming 'stuck' in a corner of whatever geographic, tactical, or logical space is being searched. This is 'run-and-tumble' locomotion applied to gradients of subjective probability that the goal will occur, a kind of epistemic 'nutrient' diffused through the space of possible actions, analogous to the chemical cue-gradients to which bacteria famously apply the heuristic. Jablonka and Ginsburg define life and consciousness as teleological domains: living defines goals for living beings that are impossible for non-living things: survival, development, growth, healing, reproduction, and regulation of the conditions of health. Similarly, consciousness frames novel goals for its subjects in distinctive forms such as valenced hedonic feelings, preferences, needs, drives, avoidance of feared outcomes, and pursuit of valued activities and ends. The authors' term vivaciousness refers to the distinctive dynamics that constitute life, in juxtaposition to consciousness. Both are characterized by intrinsic agency and plasticity in the sense of adaptation by means of spontaneous exploration-and-stabilization, including generation-and-selection dynamics in evolutionary and developmental processes, and learning. What is the relation between vivaciousness and consciousness, between living and experiencing? Jablonka and Ginsburg pose a radical hypothesis: consciousness is a special case (or subcategory/subtype) of vivaciousness: "In neural organisms, vivaciousness includes the dynamics of the nervous system... In sentient organisms these neural dynamics have evolved to become the dynamics of consciousness." (p 10) Framing consciousness as included within (or emerging from) vivaciousness, and moreover, placing exploration-and-stabilization dynamics at the heart this emergence, invites two questions of immediate interest from a phenomenological perspective, which I shall consider here:

- First, within lived experience, what spontaneous activities unfold with the character of adaptation by exploration-and- stabilization?
- Second, how does its basis in vivaciousness shape the intrinsic dynamics of consciousness? In what ways does consciousness bear the form of its emergence from vivaciousness?

III SPONTANEOUS ACTIVITIES IN CONSCIOUSNESS

In Husserl's phenomenological theory, consciousness is modeled as a dynamical system of continuous, spontaneous interpretive activity, in which the full sense of an experience is constructed from the raw material ('hyle') of each moment's sensational, volitional/kinesthetic, and hedonic data. The interpretive, sense-making, activity (or 'noesis') of consciousness unfolds as the updating of this 'impression', coupled to a constantly-being-resolved subjective past and continuously-being- anticipated-and-navigated subjective future. The spontaneous act of retaining previous momentary impressions, of holding onto each impression while allowing it to recede from its immediacy, in juxtaposition to the newly received impression, is foundational to consciousness. Indeed, it computationally scaffolds the possibility of all temporal experience, as the subjective past is constituted by a sequence of retained impressions of previous moments (Husserl 1964, Zahavi, Trestman 2014, 2016), and this sequence both a) allows for the experience of change or temporal flux, and b) is basis for the projection of the subjective future, Subjects not only experience temporal perspective, or 'depth' (Jablonka and Ginsburg 2022, Trestman 2014) but dynamical temporal perspective: we experience time as field of temporal flow, in that we track individual moments (or momentary stimuli —a moment is usually tracked by its most salient feature) as they 'recede' away from us into the past, or 'approach' from the direction of the future, analogous to the way that we experience an optical flow field by tracking 'static points in a visual field', with position and trajectory in the field simultaneously a) being defined in relation to the observer's perspective, and b) collectively constituting that very perspective. This is possible because what is retained at each 'point' of the subjective past is the full sense of an experienced moment, including its connection to its subjective past via retention, and its open-ended subjective future. This is also implied because subjects are capable of experiencing surprise as a mismatch between actuality and prior expectations. Retained expectations shape the experience of each moment, as well as the ongoing dynamics of situated behavior, because surprise is a powerful factor in recruiting attention. The subjective future is constituted by a continually evolving, branching tree-structure of predictions based on the contents of the chain of retained moments constituting the immediate subjective past, against the subconscious background of prior experience available to be recruited by association, and the medium-term, peripherally conscious, contextual awareness of current conditions. The branch-points in this tree are degrees of freedom in voluntary action—possible courses of action that can be chosen. In other words the subjective future is open in terms of what we may choose. The experience of agency is therefore highly entangled with perception and awareness of the environment, and all are constituted in the continuously active branch-and-collapse dynamics of the subjective future (Trestman, 2014, 2016; Yoshimi 2016). Computationally, choice can be understood as a kind of auction or inhibitory-competition process among branches of the subjective future: branches leading with high subjective likelihood to outcomes of high salience and positive valence win out over branches with low subjective likelihood (due to mismatch of sensory predictions and actual sensory observations), negatively valenced outcomes, or insufficient salience. The relation between hedonic values and goals is one of mutual constitution and ongoing entanglement, as intermediate goals may become desirable by causal/probabilistic association with their consequences, but conversely, what specific goals outcomes are worth pursuing must be discovered through evaulative experience. Phenomenological theory hence supports Jablonka and Ginsburg's claim that spontaneous exploration-and-stabilization underlie consciousness' capacity for adaptive plasticity. It can also elucidate how certain learning processes are intrinsic to consciousness, and in a sense the dynamics of consciousness can be seen as a learning process as a whole. The addition of each momentary phase to the subjective past entails an update of the dynamic sense of the evolving situation; consciousness is a constant process of learning what is happening and what to do in the moment, overlaid with a process of learning how better to learn what is happening, what is about to happen, and what to do next, in the future. Each experience of a novel configuration of situational features (distributed across the subjective past, present, and future) entails the possibility of subsequently recognizing that configuration as familiar, and of conceiving of it (e.g. in anticipation) with a veracity forged in the experience of the configuration as actual. It also entails the possibility of recollecting the episodic experience by traversing the associations between moments (or parts of moments) that are forged through retention when they appear in sequence. The strengthening of associative connections among the static or dynamic components of an experienced configuration also shape the way anticipations arise subsequently, presumably according to loosely Bayesian heuristics. Experience implies the logical and computational possibility of conscious recollection, but particular conscious experiences had by conscious creatures follow quirky, idiosyncratic dynamics constrained and driven by the concrete facts of the creature's life. Extended, effortfully, attentive, episodic recollection is a costly ability to develop and maintain, so humans are in the small minority of lineages that have developed it extensively. For conscious creatures, learning is a change in behavior, an experiential phenomenon, and, in semiotic terms, a growth of the set of meaningful sign relations present in the environment, entailing the growth of a repertoire of meaningful ways of interacting with the environment (enacting affordances). At the intersection of phenomenological and computational considerations, this depends on the ability to recognize aspects of one's current situation as familiar-from-experience, predict possible trajectories of the current situation based on the sequences of those previous experiences, and to navigate the branching paths of the future-becoming-present, driven by needs and urges, seeking pleasures and avoiding pains.

IV HOW VIVACIOUSNESS STRUCTURES CONSCIOUSNESS

As low-entropy chunks of an observable universe in which overall entropy inexorably increases, living organisms must expend effort in order to continue to exist. The dynamical goal-hierarchy of any biological system's activities, taken as a whole, must conform to (takes its shape from) the requirements of self-maintaining against the general increase of entropy: by discarding and rebuilding components, transforming material components and transporting them across the boundaries of internal subsystems as well as between the body's interor and the environment, and other energetically expensive operations. This is often true concurrently at multiple levels of compositional hierarchy: cell, tissue, organ, organism, social group or mutualistic association (Trestman 2010, 2011). Therefore, regulating the supply of available energy to other activities imposes a functional constraint which must operate at various levels of control hierarchy and spatiotemporal scale. Simply put, the success of any attempt depends on having sufficient energy. All movement, development, healing, growth, chemical transformation, and computation, which occur in living animals during even the most 'passive' states of physiological rest (such as sleep), are metabolically active, consuming stored energy. The energetics of effort are manifest in human consciousness both as distinctively 'energetic/energic sensations', such as striving, force, tension, or resistance, and also as dynamic patterns of kinesthetic, sensory, and hedonic experiential primitives, or 'kines-

thetic flows’ (Sheets-Johnstone 2017, Walton 2017). Moreover, there is a ubiquitous quality of available energy that varies over time and seems to modulate the experiential dynamics of volition, sensation, affect, cogitation, memory, and by implication the spontaneous exploratory activities that constitute the unfolding of consciousness. The degree of spontaneous exploratory activity (i.e. the expression of vivaciousness sensu Jablonka and Ginsburg) seems to strongly autocorrelate across types of activity in experience; I propose the label vivacity to refer to this posited dimension of variation in the degree of spontaneous expression of exploration-and-stabilization dynamics of vivaciousness/consciousness.
Low vivacity experiences correspond to:

- lower degrees of spontaneous exploratory drive (and behavior);
- bias/preference for rest;
- general lag and dampening effects in the relation between kinesthesis/volition and its sensory consequences;
- generally longer performance time and greater experienced effort required for a given action;
- sensations of fatigue, strain;

Moderate vivacity experiences correspond to:

- contextually appropriate spontaneous exploratory behavior;
- smooth, controlled response with minimal error;
- sensations of comfort and ease;

High vivacity experiences correspond to:

- high levels of spontaneous exploratory drive (and behavior), potentially to the point of disrupting performance of deliberate tasks;
- bias/preference for high degree of general or specific stimulation, challenging activity (discharge of effort);
- relatively high rate of errors of overly forceful or uncontrolled response, i.e. less effort required to produce a given effect, more effort required to control precision of action;
- elevated rates of false positives of recognition and inappropriate responses;
- sensations of urgency or need to discharge action.

These patterns are hypothesized to apply across all sorts of consciously regulated voluntary and quasivoluntary activity, including effortful mental acts as well as the performance of overt physical work. The experience and performance of any activity is modulated by (among other factors) the subject's level of vivacity; the same action/kinesthetic flow from a subject's repertoire can be performed more or less urgently or calmly, hastily or carefully, smoothly or sluggishly or jerkily, etc. Vivacity has its own distinctive dynamics. It seems to have a kind of inertia: it takes time to either 'warm up' or 'cool down', i.e. transition from low to high vivacity states or vice versa. The dynamics of vivacity are entangled with the individual's perception of the situation, inside and outside of their bodies. Generally, anticipated harms recruit energy for their prevention, and attractive possibilities recruit energy for their pursuit. Sudden awareness of danger triggering a 'fight', 'flight', or 'freeze' cascade of mammalian physiological (and cognitive) preparations for action is the most dramatic manifestation. Energetics is also phenomenologically evident in competition between activities. Some combinations of activities compete for energy because they exclude each other entirely, forcing an individual to choose. Other combinations, such as running and carrying, or navigating and reminiscing, can be performed together at some combination of costs: additional effort, decreased performance, and increased risk of failure, exhaustion, or injury. Higher overall vivacity seems to correspond to better management of competition between activities; this makes sense both because extra computational work is required in adapting the performance of each to accommodate the other, likely performing each in a way that would not be performed other than in the combination, perhaps because they are suboptimal in the absence of the combination. As discussed above, the branching structure of the subjective future implies a kind of computational multi-tasking intrinsic to consciousness. This entails a competition for energy and other constrained computational resources between the demands of maintaining the branches. Thus, the dynamics of available energy permeate the most intimate and fundamental levels of experience, in the form of one's capacity to flexibly and creatively intuit possibilities, or, we might say, degrees of freedom in the subjective future. This may explain why Danziger et al. (2011) found that the rate at which judges grant parole application varies at an astonishing 65resting. This example illustrates that the nitty gritty details (in this case, blood sugar) of vivaciousness make themselves felt, literally, even in the "symbolic mode of being" Jablonka and Ginsburg call reflectiveness, concerned with "shared, communicable and veto-able representations of norms." The example illustrates all too vividly the peril of ignoring the connections between energy and possibility, or of seeing reasoning or consciousness as abstracted from lived biological reality. For humans, the dynamics of global vivacity are regulated by the autonomic nervous system (ANS), via control of heart rate, blood pressure, and glycogenolysis, which influence how quickly energetic fuel becomes available to muscles and brain for kinetic and computational work. Are the interconnectivity of experienced available energy, context, mood, action, and physiological factors related such as breathe and heart rate therefore 'mere' contingent details of our particular mammalian biology? Or can they tell us something more universal about consciousness itself? While the former might be true if arbitrary contingencies of the mammalian autonomic nervous system imposed the dynamics of vivacity on our consciousness, it might be more accurate to say that while various mammals' ANSs implement the dynamics of vivacity (in mammal-specific and more fine-grainedly taxon-specific ways, including individual quirks), at a deeper level they are imposed by the energetics of action (including computation), as a set of fundamental requirements on coherent organization of goal-directed behavior of a certain complexity (occurring in cell-based life; of course, all bets are off if this assumption is relaxed). While data is limited, arthropods that have been studied show similar autonomic regulatory capacities to vertebrates, relating circulation and respiration to perceived contextual factors in preparation for action, despite the absence of clear homologues of vertebrate ANS structures (Canero and Hermitte 2014). Similarly, in cephalopods, no clear autonomic regulatory nervous system has been resolved, but autonomic regulation evidently occurs; respiratory ventilation has long been used by researchers as proxy for general arousal, as it is known to increase in correlation with behavioral activity, but also in the absence of activity in response to (learned or instinctive) cues of either danger or rewards such as favored food and potential mates or competitors (reviewed in Mather 2021). Given their dramatic bursts of energetic activity involved in their antipredator, predatory, and social interactions, this is hardly surprising. Mechanisms regulating rates of metabolic production and physiological circulation of ready-to-use energetic fuel to match conscious awareness of contextual requirements for action, are predictable in any complex, actively embodied creature.

V CONCLUSION

Vivacity, vivaciousness, and consciousness in arthropods (or cephalopods, or extraterrestrials) surely differ in many details from in mammals, as do other aspects of biology. Analogously, arthropod vision is quite different from vertebrate vision. It also varies strikingly between groups of arthropods, with a wild diversity of numbers and geometric configurations of resolving lenses clustered into toolkits of functionally specialized eyes. Nevertheless, crustaceans, spiders and insects can all resolve, recognize and categorize images, visually track objects through space, and navigate through cluttered terrain using visual orientation to landmarks of varying distances. Just as the logic of projective geometry imposes constraints on visual systems, the energetics of effort impose vivacity as a constraint on the dynamics of consciousness. This should hold for any conscious systems that share similar thermodynamic background conditions to terrestrial cell-based organisms, and would hence need to dynamically regulate the recruitment of energy in proportion to contextual requirements for action. This seems a prime example of Jablonka and Ginsburg's claim that the dynamics of consciousness depend on the dynamics of its underlying living substrate, i.e. vivaciousness. If indeed the energetic requirements of action, cognition, and consciousness itself are present for all conscious creatures, it follows that managing energy is an inelimable component of 'semiotic competence', the ability of a creature to "develop models of (aspects of) their environment, which result in a capacity to navigate in the environment"(Campbell, Olteanu, and Kull, 2019). Creatures must learn to negotiate their own energetic limitations and requirements when perceiving affordances and choosing courses of action. For example, whether a given tree is climbable depends on the agent's energetic state, among many factors. And just so for all work, including the metabolic, mechanical, computational, semiotic, experiential, etc., works that compose the very processes of life and consciousness. Given its role at the crux of all conscious choice by living creatures, the energetic dimension of consciousness, what I have called vivacity, bears further exploration from the semiotic, phenomenological, bio-cognitive, and evolutionary perspectives integrated within Jablonka and Ginsburg's framework.

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