For Value or for Worth? Part 2: A Neuroeconomical Thought-Action-Mood-Space Modulated by (Un-)Certainty as Sign- or Goal-tracking

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Abstract  Epistemology requires trans-disciplinary logics for convergence. Here a logico-geometrically expanded cyclical version of the classical French temperamental and anxio-affective thought-action-mood-model, “dyn4-TAM-cube”, harboring Appropriation Waves (AWs), encounters an effort-related node of present neuro-economical debates: the cyclical relation between “value” and “worth”. Accordingly, as a fundamental of the brain, this essay’s second part continues to explore the alternation between symbolic frontal 4-dimensional (Halford) processing (“4D-Thought”), and high-dimensional parietal (Rizzolatti) intellect- lectual intuition (“5D+-Action”), as balanced according to Richard Sorrentino’s prime motivator trait (Un-)Certainty Orientation (“UO-versus-CO”) interacting with “Mood”. The two mentally processed transitions between these low- and high-dimensional domains, “4D-T~” and “5D+-A~”, are complexity-reductive Perception P{A⇒T} and exponent “appropriations” in dyn4-TAM-Space Modulated by (Un-)Certainty as Sign- or Goal-tracking.

Keywords  (Un-)Certainty Orientation, Sign-tracking, Goal-tracking, Computational Psychiatry, Relational Complexity, Neuro-economics, Prediction Error, Cortico-subcortico-thalamo-cortical Circuits, Mast Cells, Mixed Bipolar Disorder

1. Introduction

The second part of this essay [2] proposing a more integrated and developed classical framework related to temperamental and anxio-affective “appropriations” in recurrent sequential waves, and attracted by permuted states, “dyn4-TAM-cube”, (see abbreviation code), provides an encounter with currently rapidly unfolding convergent neuro-economics.

2. Interfacing 4DT~ and 5+DA~: “Value” and “Worth”

The opposite cognitive attitudes in facing unexplained complexity, which manifest as opposite human performances [1], in the dyn4-TAM-model [2] occur at the interfaces between low- and high-dimensional processing. The present proposal states, that in analogy to uncertainty-oriented humans (UOs), sign-tracker rats (STs), after engaging in the “perception of value” P{A⇒T}, perform vigorously in exploring anticipated potential discounts in effort, and secondary advantages in exchange of values, and goal-tracker-rats (GTs) instead in the “intuitive intention of worth-appropriative moves” I{T⇒A}. Where the former sangui-nerve excel in reducing complexity, and thereby hopefully effort, into more sophisticated models of appropriation, the latter choleric excel in keeping or expanding complexity. In order to substantiate this claim this convergent review aggregates more detailed structural analogies as a first step to hypothesis-testing.

Such temperamental variety, as other intra-group diversities [3], may favor fitness of groups and societies’ welfare [4] and are at the core of conflict and cooperation. Such value/worth-dualism also complies with the old stance, that the market “value "exchanged (...) is the quantity
of labor (…) commonly taken in producing them.” [5]. Labor in the individual appears as “effort” - as reflected in e.g. tonic extracellular striatal dopamine [6]. Thus abstract value represents production costs, which ultimately consist of e.g. human effort.

This duality appears as biologically hard-wired. The phylogenetically newer anterior lateral OFC processes such abstract (monetary) “value”-rewards [7,8], which overcome subjective effort as incentive appetite probably signaling the opportunity of unusual bargain, while appropriated “worth” results in anticipatable, utility- reflecting affective “hot-spots” [9]. Hereby even the temperamental shapes of “utility” curves seem to be accounted for, yet “value” and “worth” are commonly considered as interchangeable [10].

3. Dual vs. Mixed Motivational Updates

Reward prediction error (RPE) signals, which update about the reliability (“precision”) of cues (for opportunities), were first discovered in midbrain dopamine (DA) neurons [8, 11-13], and then in additional sites including - for punishment - the habenulae [14], striatum – also in humans [15].

The scope-specific single-step updating via eligibility-targeted plasticity [11] accordingly is not a backward modulation, albeit still connected to specific needs. In fact pairing a CS(1) first with US(a) and then with US(b) is equally efficient for appropriative action, but blocks learning from a new CS(2) about US(a)2. Rather than supporting an additional Konorskian general activation [16], such a block, deviating to another US(b), would allow to stick to an established joint cue about less effort in appropriating both.

A recent simulation [17] of sign-tracking (ST) underscores an antegrade capacity of the cue to reawaken a reward pertinent to a need, which then engages in a second, interrelating process. The niche-dependent relative efficacy of goal- or sign-tracking is not considered and these “rewards” are added and not multiplied.

Only the reminder that appropriations are motivated by two processes [18], which in dyn4 occur at “Intention” and “Perception” interfacing between 4DT− and 5+DA− (Figure 1), which therefore ought not to be collapsed, seems to clarify several neuro-economical issues.

4. Disincentivizing at the Interfaces

Besides cognitive efforts, and many other intricacies of motivation [19], motor efforts impact future “rational” best-reward-for-least-effort-choices and subjective evaluations (like regret) through a same network. This correlates with reward and inversely with effort and involves SMA, itself corresponding to avoidance, and dorsal ACC’s caudal portion for calculating motor costs. Not decision for action, but seeking of reward is activated by the vmPFCi [20].

As dissociated appear the shape and site of the action-devigorating impacts a) of expenditure of effort, which is lesionable at the ACC (in the cortico-subcortico-thalamo-cortical circuit, CSTC, for 5+DA) or by unilateral sites of mPFC in rats [21], and b) of delayed reward, which is lesionable at OFC (in the CSTC of Moods) [22]. While ACC and the anterior insula (aINS) perceive, P{A→T}, efforts [23] from 5+DA, delays might allow worries about extra efforts (4DT), to dis-incentivize, less I[T→A], at the ventral striatum and the vmPFC. At least for STs effort-related fatigue usefully prevents further losses by stopping exploration of tempting cues [24].

Figure 1. The cycle alternating 4D-Thought and 5+D-Action, as illustrated through the “Thinker” and “Marcher” by Auguste Rodin, hides Appropriate Waves (AWs). At its first transition of Perception of external and internal feedbacks from effected change, some signals become contingent reward-x-specific cues, A(cueRx), inspiring the early AW. Some of these become incentive cues of a different kind, which hint to a learned discount in the expected appropriative effort (F). Intention urges for action when the expected cost, felt as effort +F, is expected to be more than matched by the perceived reduction of Need by reward Rx as 5+D-Aint(N-Rx).

Less effort as a negative reinforcement might provide a further “facilitation of a specific form of neural computation that results in conditioned approach behavior” also by mesolimbic dopamine, which here would not act as an anticipator of reward [25].

The principle of least effort also guides many decisions when building Intentions (I[T→A]) to act. As a loss-minimizing strategy – under interacting conditions of exhaustion and scarcity [26] – it is computed at the frontal pole as effort under risk [27]. In dyn4 cues instill “Hope” to overcome the effort (transition “e” in part 1, Figure 3). Maximal own expendable specific need-proportionate effort (“Effme”) therefore remains a crucial ceiling parameter, and the inverse of “value to me”.

While decisions localize to the OFC, foragers rapidly adapt their means or goals to changing surroundings through such a function of possible maximal effort and attainment through least effort, i.e. of “resources and opportunities.” Herein the dorsal ACC [28] and the posterior cingulate cortex may at times signal the “pressure to pursue unlikely choices” – preferred by uncertainty-orientated STs [29].
5. Prediction of less Effort or of Reward

The ubiquitous “reward prediction error” (RPE) in most current accounts (but not in all experiments) could probably be smoothly replaced by a RPE normalized into RPE(-Δ%Effme) through multiplication with a ratio expressing the reward-specific maximal expendable effort, integrating past specific expenditures and regrets, and also the present “energetic state” [26], divided by the presently anticipated, at times negative, discount, as indicated by incentive cues.

The perception of the cue is temporarily closer to the evaluation of anticipated effort, and therefore more easily associated with it, than the outcome in terms of utility (“worth”), apparent only after consumption. This worth divided by recent effort answers to the question “Was it worth the effort?” - risking regret [31] and updates the net RPE [32].

5.1. Common and Individual Economic Comparison

The need for comparison of rewards, often without a “common quality”, calls for a ranking on a “common scale of values”, on which the encoding of the RPE as “subjective value” is proposed as a, questionably, “ideal way” of steering economic decisions [31]. This “value” in reality though, as we can see, is a variable composite of worth (utility) and, at times incentive, value (effort), which is hidden behind of-ten dichotomic decisions. The variation of rewards in only one attribute is said not to allow the “isolation” of subjective preference - as far as sooner, more certain, and more should be preferred as better [31]. But beyond this we want what we like at discounted objective and subjective effort, thus the RPE changes to the residual RPE(-Δ%Effme).

The closing e.g. consummatory end of the AW perceives the feedback P{A→T} from 5+DA-led actions through evoked external and internal reactions, and activates instrumental learning. The update of RPE(-Δ%Effme) in 4DT→instead learns from spared, or increased, momentarily anticipated effort, not from outcome [8,11].

Accordingly ventral striatal neurons signal “reward” or rather RPE(-Δ%Effme) before the rat’s decision, the OFC only afterwards.

In market economics goal-specific objective effort, being the essential aversive variable related to appropriation, can be called “value”, and sellers initially cash in on unaccustomed economies in effort since hereby they can buy “any” good representing more effort (value) with less effort, which on average holds true after transformation into subjective residual value represented by RPE(-Δ%Effme). In dyn4 this momentarily advantageous (positive) reduction of value figures as perception of a resource-saving cumulative 1-D-index of net appropriative experience relevant to the early AW-module Worry-T→/a→/m-. The dynamics of actions and the individual utility of things and services (“worth”) instead attain to (5+D-)Action.

That such acquired evaluative neo-Pavlovian “reflexes” obey to a ceiling of effort may find support in the resurrection of memory and learning in the study of primary sensory cortices [31]. It also seems even compatible with the various trait-like marginal utility curves [31] generated from “rational choice” via the unlikely “definition of value” as that from which “one can’t get enough of” [11] in the pure monetary form. Nor anything formally scrunches thereafter when utility is taken to be correlative to (…) want - or by col lapse with “worth” - what “a person is willing to pay” for satisfaction [33], in some other currency. Finally, since UOs, and presumably STs, are attracted by the unknowns of computable risk calling for modeled discounts in effort, they can be expected to enjoy the pure unsaturable monetary shape, of which imponderable worths only cause impure inflections.

5.2. The Divisionary Focus of Habits

This dualism of processing styles, here reflected through “UC-CO-orientation”, is primarily non-habitual and thus different from the two “systems”: either “quick, intuitive, and effortless” or innovative “slow, analytical, and deliberate” – thereby “overcoming intuition.” [34]. In dyn4 these map to, at first non-habitual, intuitive ways of 5+DA and to more conscious symbolic processing in 4DT, often struggling with what it perceives (A→T) of the complexity of 5+D-Action and reaction.

Such model-based learning (MBL) besides the testing of hypotheses by relational thinking nevertheless also involves more Gestaltian [35] 4D-pattern searches, than even intracostly costly searches through trees [36].

5.3. When Scare Prefers Grasp over Model

Only the dorsal ACC and the aINS [37] related to 4DT- and M-, not the parietal cortex for 5+DA, harbor the highly intuitive rapid Von Economo-spindle cells [38], which might have a role in the reductionist grasping “Thought-about-Action” I{T→A} that provides newly adaptive fast-and-frugal heuristics. Such prove successful under both habitual and erratic circumstances [39] and are triggered by often just one cue providing “model-free” learning (MFL). Unexplained adverse complexity via input from locus coeruleus can block experienced model-based functioning in the ACC in favor of such erratic behavior, whereby, at times “naturally” simple-minded CO-actors [1] become as unpredictable as their surrounds.

5.4. When Modeling Becomes Useful

Yet when routines stop working, UOs are needed for their renewal. Then even the liking system adapts: once cake is lacking you’ll like bread! (Un-)Certainty-orientation theory [1] shows, that the related affective valences (M-) cannot be taken for granted, but reflects a stable cognitive trait.

The Uncertainty- oriented (UOs) are enabled to maintain the effort required for the conceptual reduction of the complexity of reality by their higher threshold for cogniti-
ve-effort-related dysphoria, and by their, at times even high intellectual pleasure, Flow [41] denoting the process from Bliss to Interest in dyn4.

The Certainty-oriented (COs), being unblessed by opportunity-optimizing modeling tasks, instead use rapid reductive “chunking” into essentially simple commands, to govern, intrinsically complex (!), habits.

While lack of mental flexibility can lead to apparent CO, this usually comes with some loss of intelligence, which is not a feature of COs [1], but rather due to disturbances at the medio-dorsal thalamus [42]. The focus on such cognitive efforts presently rejuvenates psychiatry [43, 44].

5.5. Collapsing Duality by Arithmetical Lumping

One account of the ST-problem [36] avoids this double character, or “disunity” [45] of “value” or “worth”, by proposing a halfway mixed dual system, whereby the STs are judged by the standards of the cage to be underperforming. MFL through sequential “hot-or-cold”-attempts, here represents “both habits and incentive salience” of Pavlovian “reflexes”, while tree-comprehensive permutational, alias model-based, 4D-T-learning (MBL) supposedly relates “to goal-directed valuation, be it instrumentally or in Pavlovian settings”. This commixture, ensuing from a crude reduction of intentional planning, cannot represent habits as entrenchment of instrumental learning nor decide the issue.

5.6. Mood Interacts with Attitude towards the Not-yet-explained

When it comes to positive, or negative, affect, what is interesting therefore is, that in the COs the valence of M-decreases with increasing 4DT-; whereas the UOs enjoy intellectual adventure proportionally [1]. Actually M-interacts with (Un-)Certainty-orientation: while UOs or COs are defined under the premises of a longing for “maximal achievement”, under the clinically depressive premises of a minimization of further losses, the two extreme types, at a certain point of prudence, switch into their mirror cognitive style [46, p.6]. Rats who have lost goals [47], or which know them for longer [48], switch from GT to ST, and certain “animals shift their preference from stable to variable food sources under (...) increased physical effort or falling energetic(s).”[26]. Furthermore both orientations gain with high spirits, which steepen their opposed regressions.

Yet the yet-to-be-explained in foraging become dramatic only on arid, not on lush meadows, so at the end of despair COs, after transient UOs-ness, would become COs again, sticking to live-saving solutions. Yet goal-tracking rats (GTs) with empty pots would start searching farther away than desperate STs.

Teasing through contextual unknowns increases ST further [50-52], maybe because then cues signal lesser efforts unreliably [53]. Tracking-attitude may also depend on status, which is partly inborn: Dominant members often eat first and submissive members are more successful if they use innovative hypotheses, i.e. if they look more out for cues, than for the food proper, since in the first case they may eat unnoticed by the dominants, while in the second case, they may end up only knowing where the food is others eat.

5.7. Hiding Circularity

The circular account is obviously lacking in the recent Bayesian “Active Inference” model, which seemingly solved circular explanations of “reward”, whereas this circularity just mirrors the essence of AWs informed by attributes of homeostasis or growth and as such should not be solved. The model in fact makes unpredictability, precision and salience collapse into “Active Inference” or what midbrain DA supposedly codes for, conveying how (active) “perception minimizes exteroceptive prediction errors and action minimizes proprioceptive prediction errors.” [54]. The model in fact reflects the again truly marvelous discovery, that certain dopamine neurons under conditioned stimuli proportionally code for unpredictability of reward [55], but unpredictability unduly replaced reward and salience, whereas reality is more complex [13].

At least in the cortex response variability furthermore seems not to be a solid foundation, since any stimulus causes its decline [56]. Albeit unpredictability, precision and salience determine the value in finance industry, they do not account for all facts in the life of rats.

6. Mast Cells, Histamine, and Thalamus

Mast cells (MCs) enter the brain during development, and these cells are replenished [57] or augmented by additional MCs which rapidly immigrate upon signals, which reflect social events, germs, drugs or physical changes [58] or, why not, sexual rubbing. Cerebral MCs are usually found to be scarce, yet most densely present at the thalamus, the habenulae, the olfactory bulb, and within the meninges. Via the braking habenulo-mesencephalic loops [59] MCs guard the blood-brain barrier [60,61] or trans-granulate into neurons [62], and thus probably modulate incentives.

The perivascular access to the parenchyma of these sites is wide open in the subcortical [63], but obliterated in the cortical locations. The induction of MC degranulation in the thalamus of rats caused excitation (70% in females, 11% in males), or inhibition (7% in females, 33% in males) of thalamic neurons [64]. Positive affect accompanies the behavioral invigoration triggered by MCs under several social circumstances, e.g. during courtship [65] in the medial habenulae. Female rats after cohabitation increase thalamic MCs within the medial geniculate and four other thalamic nuclei [66], whereas in mice not thalamic, but meningeal degranulation of MCs correlates with wakefulness and stimulatory tone in the CNS [67].

6.1. Mast Cells and Thalamo-frontal Driving Feedbacks

Dominant thalamo-frontal influences have been recognized in several domains [68-70]. These occur within the
largely segregated, and thus dimensionally orthogonal, CSTCs [71], wherein cortical inputs to the basal ganglia are conveyed back to the cortex via the thalamus. Several of the many MC mediators [72] and effects could plausibly modulate the thalamus. While within the CSTCs the striatum is driven through glutamate by plentiful excitatory input from the PFC, and by thalamo-striatal connections, MCs intriguingly only potentiate excitotoxicity via histamine (HA) [73], but are not glutamate-releasers, while requiring it for degranulation [74].

Nevertheless HA, commonly of MC origin, selectively potentiates N-methyl-d-aspartate receptors (NMDARs') allosterically on a magnesium-sensitive NR2Bi-site [75] also involved in hallucinogenicity [76]. Such an increase of glutamatergic activity could plausibly impact on the functioning of CSTCs. While brain HA was normal in mice deficient in MCs, HA in rats was shown to stem from MCs up to 90% in the thalamus and to half in the brain [77]. The latter findings presumably also reflect a more activated state of MCs, wherein large amounts are secreted. Rat cerebral MCs were nearly all thalamic and specifically found in three areas and in the sign-tracking-related paraventricular nucleus of thalamus (PVT) [78].

6.2. Mast Cells as Agents with Destination and Destiny

It is tempting to investigate, wither cohorts of MCs, after peripheral priming of destination and destiny, would often migrate to the brain, where they would lastingly influence subcortical and cortical modules. In the striatum they interact with perivascular nerves, which are the fastest first responders for midbrain DA [79], or with cells of the neurovascular unit. Thereby physiological inflammatory processes could be pushed beyond temperament to “affective temperaments” [80], anxio-phobo-affective diagnoses or to soft, yet often deteriorating, bipolar mixed states [81].

Specifically the depressive switch into opposite tracking or (Un-)Certainty [1,46] mode could be modulated by MCs primed to cause “depression” (instead of hypomanic lesional “vigor”) when reaching the PVT, via the thalamo-perforate and thalamo-geniculate arteries.

The PVT in any case achieves its importance for cue-reward pairing through its broad subcortical and prelimbic cortical afferents and glutamergic efferents [82].

7. Scopes and Outlooks

The achievement of logically expressed convergent high-quality research is a daunting task, especially if practical clinical utility remains a goal. Huge global projects like the Research Domain Criteria (RDoC) initiative are under way [83], which astonishingly removed movement from the classical triad [84]. Furthermore especially the understanding of intrinsically dimensional topics, e.g. of CSTCs providing dimensional data, seems relevantly hampered by the habitual avoidance of direct acquisitions of “unplugged” i.e. intact patterns, conservable e.g. through the Configural Frequency Analysis of Gustav Lienert [85, 86]. This intriguing neglect could be related to UC-orientation [87].

This essay, which takes advantage of the author’s tiny context, strives to contribute a sketch of an anxio-affective framework for such convergence to epistemology and clinical talk alike, dyn4 being also progressively expanded to dyadic or family system relations. The essay focuses on an Aristotelian geometric classically triadic dyn4-T-A-M-model newly interpreted as contrast between private low-, and public high-dimensional processing. The comprehensive AW, as inscribed in the cube and attracted by its dichotomic permutations, apparently has not been proposed as the basic sequence of behavior before.

7.1. Triadic Models in Clinical Psychology

An entwined “adolescent” triadic model [88,89], which centered on maturing balances of self-control [90], had instead cut across the T-A-M-dimensions in a not comprehensively orthogonal way. It generated a three composite factor balance between a) a mainly subcortical cognitively (actually movingly) impulsive non-delaying approach driven by reward, stemming even from “risk taking” (Joy-t-A-M~), b) a prefrontal cognitively reflected overall control (T~), and, beyond “dual systems”, c) an amygdaloid emotionally deranged avoidance (a~, m~). All the same e.g. it doesn’t accommodate amygdalar salience or striatal expectancy [91] or the affective temperaments [92] well - nor the “inextricable” “interactive dexterity” emerging from studies, not allowed to be constrained into mechanistic orthogonality [93], albeit maybe just this would support the sought independence from valence, besides providing systematic complex predictions amenable to non-tautological falsification. Classically triadic instead is the influential associative, sensori-motor, and limbic tripartite division [59], albeit some sensations are low-dimensional.

7.2. Are Neuro-economics “Dual or Not”?

Intervening also into the present (neuro-)economical debate this essay calls for “circular” experiments avoiding undue “collapse” between low-dimensional “value”/effort and high-dimensional “worth”/utility. This is now strongly supported by the first localization of the positive human interactive “value-to-utility transformation” to the inversely activated dorsal anterior mid-cingulate cortex (dmPFC). The connectivity of this is positive with the probably uphill inferior frontal gyrus [94], related e.g. to perceptive “confidence” (certainty) [95], and negative with the probably downhill Nac providing intentional subjective “valuation”. Within the OFC instead “value” seems stored behind, and “worth” in front [96]. Others shed doubt on the necessity of emotions as mediators of mesolimbic dopaminergic effects. e.g. on feeding, but explore a more abstract “facilitation of a specific form of neural computation” [97], maybe an
expansion of complexity.

Impressive reviews of transfer [98,99] concede that despite guaranteed rewards, cues still work, whatever the “worth” [100], while others focus on “efforts” [101]. Importantly the “dual” arguments also apply when “worth” equals inviolacity [102].

By conceiving the incentivity of cues to be due to opportune effort-reducing and thus facilitating means signaled by the cue, their three [103] attributes – attractivity (for agent’s attention or approach), instigation of effort to reach them, energizing of appropriation of reward – can be accounted for.

An orthogonal conceptualization of the segregated albeit cortico-cortically linked CSTCs and their “intentional” function is maintained in some frameworks, at least for $A-$ and $M-$ [104], yet in a collapsed way avoiding $T-$.

Motor-related habits [108], albeit dopaminergically [109] crystallized, are still complex programs reformed away from globus pallidus [110] through various processes, e.g. TGF-B [111] or NMDAR- [112] activity on striatal DA-neurons. The lack of the latter glutamatergic input slows down learning, social contacts and forced swimming, but not effortful performance [113].

Some neuro-economically engaged clinicians say themselves not yet content [114] with their differently dual complexity MBL/MBF-approach contrasting “more complex”, “goal-directed” MBL-based behavior with alternative habitual MFL-based decision making [115]. They e.g. showed that rises in ventral striatal (VS) DA correlate with MBL-related “signatures” in dIPFC and inversely with MFL-related encoding in VS [115] - both being conceived as $4D-T-$ in dyn4. Their alternative habitual MBL-pro- cessing instead as such in dyn4 would remain “complex” as related to $5+D-A-$Action, despite requiring less $4D-T-$ re- lated conscious steering or being shielded from outcome-perceiving feedback. This delayed habitual reformating by repetition may actually detract from the problems collapsed neuroeconomics encounter in mental care.

The sufficient checking of a purportedly rapid less effortful intuitive system-1 ($5+DA)$ by a more reflective system-2 in otherwise biased decisions, has been strongly complemented by a core role of even less intuitive numerical abilities ($4DT$) [116].

7.4. Neurobehavioral Complexity Changes and dyn4

Following $dyn4$ it would have to be explored whether the CSTCs involving the ACC assigned to $5+D-A$ really show a higher e.g. fractal dimensionality than the one involving the dIPFC mapped to $4D-T$. In fact the dorsal ACC itself already produces neuro-economical [117] reductive models of con- flicting past and present experience [118] ready to feed decisions to be taken in dIPFC, linking contexts with appropriate, and therefore lastly motor strategies by producing a rich “task space” [119].

Since appropriation is the organizing principle in $dyn4$ motricity ($5+DA$) is in command of secondary parietal or primary motor areas. Similarly the CSTC involving OFC / vmPFC [120], and not the “limbic systems”, represents Mood, as they master economical emotions [121] and integrate emotionally valenced “worth” to command appropriations [122].

The CSTCs themselves being feed-forward structures show an about 500-fold quantitative neuronal reduction in “complexity” between striatum and the pre-thalamic inhibiting output components. Of these the substantia nigra (SNr) e.g. may “gain control” over cortical feedback when sparing explorative efforts [123], braking “complicated” $5+DA$. Rodent-primate homologies of CSTCs are many and also related to psychic models [124].

The present $dyn4$-account also implies that the alternating coordination between $4D-T-$ and $5+D-A$-processing is an enlightening prerequisite, beyond basic divergence and fun- neling, for any functional brain activity. This occurs within $4D-T$ and is often dealt with as top-down attention. Recent theoretical shifts towards considering the dorsal attention network (DAN) within the fronito-parietal cortices as a common substrate of “internal attention” sustaining as variegate functions as working memory, episodical retrieval of per- cepts, and intentionally complex mental imagery [125] supports this crudely mechanistic prediction on a high level of sophistication.

7.5. Effortful Controls of Thought, Action, Mood

We tend to fuse the concepts of subjective effort - the emo- tion of cost - as the felt passive brake on expenditure of re- sources, and again the overcoming active effort throughout the initiation and maintenance of effort-full processes. The steering of motor-costs is primordial, while the pleasure-systems and their hot-spots in evolution are small and marginal [126]. In humans though the costs of emotions, like the one from the urge of want, and their cognitive costs can become predominant. Thus, besides some focus on duration [127, 128], mainly the cost of suppressing emotions is monitored [129]. Fortunately affect dynamics are taking momen- tum also in the case of a likely alias of increased emotional effort suspected to be a pre-depressive signature of decou- ling from usual functional connectivity: rigid emotional inertia [130].
These modules related to effortful appropriation have just been assembled in a formidable review [131]: The ventral striatum (VS) including the nucleus accumbens (NAC) activity likely is due to a momentaneous internal Perception of the opportune simple ratio of utility to effort, which continues when utility reaches a ceiling, helped by the midbrain. The VS invigorates appropriative action and the momentaneous changes in dopamine correlate with the willingness to work, which correlates with incentive cueing, even in absence of reward! Demanded high-effort choices, which need permission by the ACC, instead activates the amygdala, which seems to aid in encoding of relevance of the former inner and external Perceptions. It gives rise to urges, also in associative learning, whereby DA is released in the NAc, and the ACC is instructed to allow for high-effort expenditures. The amygdala overall acts as a conservative or investing expense controller in front of the temptations provided by the VS.

The dorsal striatum plans, decides, and automatizes motor behavior often into habits, while it also monitors internal metabolic and even external nutritional resources. As a result it encodes specific energetic prerequisites for appropriation. Mice without DA instead die from aphagy, while hedonics and spatial learning of food remained intact. In dyn4 this preparation of Action corresponds to Intention. Within the dopaminergic midbrain the VTA and SNr interact with the striatum and thereby seem to provide the expected average opportunity on appropriation with the specific effort. Yet the amphetamine-sensitive emotional drive, as computed from the latter costs and delays combined with „subjective value“ (worth) and the variable confidence in consequential Intentions, is provided by the vmPFC. The ultimate decision is taken around the intraparietal sulcus.

In dyn4 this corresponds to Interest or Worry leading via Application or Remediation to Pursuit [2, Table 1].

The supplementary motor areas (SMAs) monitoring muscle contraction interestingly feeds into subjective effort, while through preparedness it may invigorate response or maybe inversely spare effort.

7.6. Momentaneous Fluctuations Could Confirm dyn4

This same review [131] then attracts attention to the meaningful information hidden in the momentaneous fluctuations in cognitive and physical effort. Albeit the speed-accuracy trade-off is pervasive, it becomes hidden in the context of higher rewards, by which both increase. In psychiatry instead the new validated concentration deficit disorder (CDD), former „sluggish cognitive tempo“, which has replaced most of ADHD-inattentive type, is not an executive disorder, but strangely reminiscent of a coupled inertia of $T~$, $A~$, and $M~$, related to depression and refraining from higher intensities in all three dimensions [132].

In dyn4 accurate distances are a result of $5+DA~$, while $4DT~$ is related to appropriations in a vague future and their speed. Reward-induced invigoration along the Appropriation-axis „from Need to Pursuit“ in fact causes a symmetric intensification in $T~$, $A~$ and $M~$. Through this analogy we start to consider coupled, usually skewed, simple harmonic oscillators (SHO as a mass-on-a-spring with $(-k/m)x = d^2x/dt^2$ obeyed by sin(x) or cos(x)) as a biaxial [133], not mono-axial [134] model of „mood swings“. Hereby the above momentaneous fluctuations of $T~$, $A~$, and $M~$ are modeled, which putatively correspond to the three „affective“ CSTCs. The CSTCs by virtue of their direct and (negative) indirect paths, in fact could be approximated as SHOs.

Silvain Tomkins modeling of emotions as analogue amplifiers of intensity and its first derivative over time with as prime role for muscle sensibility [135] here appears as very much to the point and compatible with dyn4.

7.7. Biopersonology and dyn4-TAM

While dyn4-TAM can probably be best mapped to a bioamine-centered model of personality e. g. by Richard Depue [136], rapidly-acting ketamine-related or cholinergic antidepressants have deviated attention from these systems (see 7.5.).

The specifically cholinergic molecular loss of function in STs [137] points strongly to the fact that cholinergic systems support anti-distractive cognitive control, whilst also allowing for attentive shifts with reorientation to cues and cue-re- responsive action [113], like approaching the goal!

Present psychological research on humans applies the concept of „ST-to-GT“ [107] and could use cross-validating tests for „UC-to-CO“ [1,46], while studying resistance to temptation or effort [106] would also test the here exposed hypothesis of homology.

7.8. Mast Cells at the Reins of Appropriation?

As to the own hypothesis, that the anatomical convergence of the three „affective“ CSTCs at the thalamus might provide access especially for mast cells [138] intruding along the posterior arteries to modulate subcortical logistics, some few observations concur. Since STs are high in ventral HC myinositol, and hereby dopaminergically incentivize Nac in Pavlovian approach [139], putative roles both of hippocampal mast cells [140] and of lithium [141], inhibiting IMPase [142], emerge, which hint to how the convergent framework dyn4 could operate in affective disorders. In fact cues become less incentive under ketamine [143], the miracle antidepressant pro-drug which acts by upregulating AMPA-receptors [144], which happens to incite [145] or to calm mast cells [146], but does not affect midbrain DA [147].

The latest review on STs [148] points also to the lateral habenulae (LHb) [149-151], and thereby, see below, also to mast cells (MCs), as a part of the food-cue-induced “motivic circuit”, and its rapid adaptions. Within a larger network [152] they help in attributing salience [153] to the point, that
the LHb drives the VTA and SNr during RPE [154]. The LHb specifically act as indirect [155,156] strong inverse modulators [153] of the DA of the midbrain’s SEEKING system [157], and the playfulness of STs is supported by the centrality of LHb for social play [158, 157]. Conversely LHb and the medial habenula (MHB) are sensitive in the non-depressed to present [159] or future punishment [160] up to learned helplessness [161, 162], produce vegetative costs of emotions [163], and shrink [164, 165] especially in bipolar depression. Drugs inhibiting LHb reverse resistant depression [166].

As to MCs [58] they rapidly intrude after psychosocial events as acute activators e.g. into the LHb after repeated defeats [167], and with parenthood [168] into the reinforcing MHB of which silencing is aversive [169]. Mastocytosis finally is depressogenic [170].

8. Conclusions

An essay “takes things from many sides without comprehending it fully.”[171], and as a vivid genre of troubled times it takes high risks to fall victim to its own boldness by losing cognitive control. Furthermore Karl Jaspers justly warned: “Theorizing has an atmosphere of its own.” [172]. Progress in fact mostly, but not entirely, occurs through painstaking continuity of endeavors critical in seeking better lives, and the Ann Kelley’s saga, certainly testifies to this. In the commemorative volume to her and also by her lab, which added successes with the STs and GTs rats, John D. Salamone contributed insights into the central role of Nac in bringing about effort-related choices [173]. This would also explain the common failures of RPE to behave in schizophrenia as computational psychiatrist, which build around it, were hoping for [176], and in this their “orthogonal” tautological Bayesian relations, which are akin to any reciprocal falsify-cation couple between theory and hypothesis, will not be of any comfort. Till date highly erudite accounts on “cues” [177] can still make it without “effort”, but the two lines of enquiry will not continue on parallel tracks with little convergence for long.

The conceptual skipping of Thought and Intention in the Perception-Action models, even in their most erudite form [178] remains puzzling (to me), while the intricacies of relational cognitive processing explore the limits of complexity of Thought [179] - till now without a factoring-in of the “UC-to-CO”-algorithm. The Intention to think, act, and feel is certainly enriched by their “economical” braking by effort, and the second response component in midbrain DA-neurons, which codes reward value as a “numeric, quantitative utility prediction error”, [180] could be a predictor of opportunity of less effort, and not of utility (worth), since it starts early enough to prevent “confusion with unrewarded stimuli and objects.”

Especially in the NAc DA participates in effort-based choices among often many opportunities in the surroundings of the niche. Variability in active effort has been referred mostly to fluctuations in subjective anticipated effort [131]. Research on emotional effort is centered on the control or suppression of emotions, and maybe today research on the neuroeconomy of confidence [181] is most on track in this area, since confidence in a cheap simple heuristic model comes at a rarely relevant [39] price of error. Also dyn4 knows the processes of Doubt or Confidence [2: Table 1] dealing with opposite interactions between model-in-4DT and Mood. The proposal that the incentivity of such cues are about specific hope, that the expected required effort will be discounted, and that Hope in dyn4 is the passage from Need-tam to Interest-TaM in dyn4, is compatible with positive psychotherapy using incentive hope.

Survival depends on movement, movement on motivation, and motivation on cost-benefit analyses of active effort expressed in passively anticipated effort? Optogenetics on freely moving rodents will soon tell us more about this [181]. The SMA’s feeding of muscle contraction into subjective effort [129] reminds us of the cutaneo-muscularly felt emotion theory of Silvain S. Tomkins [135] or recalls oro-facial mimics of „li(c)king” [182] or the clenching of teeth to increase active effort, but it can’t sustain the claim, that the felt quality of the „SEEKING” system model would allow to collapse the duality of learning in approach [157].

A recent assembly of research on circuits of positive emotions [184], to which this paper originally was submitted as an elaboration of a poster, confirmed, that the important, because extremely basic hypothesis of a reinforcement or reversal of the prime motivator (Un-)Certainty-orientation of Richard M. Sorrentino [1,46] by valenced emotion, which reveals a constituting evolutionary link between cognition and emotion, and the mast cells are just only starting to attract noticeable interest in the mainstream of neurosciences. Therefore pioneers in ST-research [126] and MC-research related to the brain [58], Rae Silver, now leader in circadian rhythms, not fully by chance are immediate neighbors in a monograph on motivation [185], and the links likely also run via “clocked” [186] and “clocking” [187] MCs in brain [58] and other tissue [188] in relation to bio-economic metabolism [189] and its central “subjective” variable effort [190].

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i. Abbreviation codes:

1. Neuroanatomy, Neurochemistry: ACC Anterior cingulate cortex; aINS Anterior insula; CSTC: Cortico-striato-thalamo-cortical circuits; Nac Nucleus accumbens; OFC Orbitofrontal cortex; vmPFC ventromedial Pre-Frontal Cortex. PVT paraventricular nucleus of thalamus. MC Mast cell; HA Histamine; NMDAR N-methyl-D-aspartate receptor for glutamate with e.g. NR2B-subunits; SNr substantia nigra (basal ganglia).

2. Psychology / Ethology: UOs Uncertainty-Oriented Individuals; COs Certainty-Oriented Individuals (Richard M. Sorrentino); UO-versus-CO Uncertainty versus Certainty “orientation”; GTs goal-trackers; STs sign-trackers; ST sign-tracking.

CS conditioned stimulus; US unconditioned stimulus. MBL Model-based learning; MFL Model-free learning.

3. Neuro-economics: Effme maximal expendable effort; RPE Reward Prediction Error; PE (Effme) RPE normalized to the present discount of previous maximum expendable effort.

4. dyn4-TAM modeling. dyn4TAM modified classic mixed bipolar disorder model; T~, 4D~T~ symbolic 4-dimensional cognitive processing; 4D~Thought symbolic 4-dimensional cognitive processing; A~, 5+D~A~ intuitive 5- or higher-dimensional cognitive processing; 3+D~Action~ intuitive 3- or higher-dimensional cognitive processing. Mood dichotomous negative or positive valence; M~ dichotomous negative or positive valence; T/t, A/a, M/m dichotomous realizations of T, A, and M in triples. P[A~T] Perception, i.e. transitions from 5+~Action to 4D~Thought; T[T~A] Intention, i.e. transitions from 4D~Thought to 5+~Action; AW, AWs Appropriation Wave, Appropriation Waves; SHO Simple Harmonic Oscillator; Worry T-a=m-Worry with much Thought, low Action and Mood.