A Frustrated Mind

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Abstract:

In this work we will develop the thesis, exposed in Uriagereka (2012) and Krivochen (2013b), that the concept of dynamical frustration (Binder, 2008), involving the tension between opposing and conflicting tendencies in a physical system, is essential when analyzing the cognitive-computational bases of language (even though neither Uriagereka's thesis nor our own limit themselves by principle to the linguistic domain). We will argue that, in principle as independent theses, there are two kinds of frustrations interplaying: an architectural frustration relating quantum and Markovian processes; and a derivational frustration relating semantic and phonological cycles. After developing and analyzing each frustration, with particular focus on human language, we will briefly explore the consequences these frustrations have on the "design" of mental faculties, and the impact our theory has on the Minimalist notion of "perfection in language design" (Chomsky, 1995 et. seq.; Brody, 2002, among others).

Keywords: Dynamical Frustration; Quantum Mind; Markovian process; Language

1. Introduction: what is a "dynamical frustration"?

The introduction of the concept of *frustration* needs a previous analysis of the concept of *complex systems*. A complex system, summarizing discussion in Boccara (2002), is a set of elements and relations, such that the following properties arise:

- *Emergence*
- *Self-Organization*

Let us analyze each briefly. The concept of *emergence* has been around since Aristotle, and it has been used in life sciences (e.g., Corning, 2002) as well as economy (e.g., Goldstein, 1999) and physics, maintaining a common core: the behavior of the system cannot be predicted as a function of its interacting elements. In other words, complex patterns arise out of a multiplicity of simple interactions (see Hofstadter, 1979 for examples and discussion). Boccara (2002) relates *emergence* in complex systems to the absence of a central controller (something which would not arise in a Fodorian modularist model, but would be expected in a Massive Modular mind: see Carruthers, 2006, particularly Chapter 1). In this work, we will work with the concept of *strong emergence*, which implies that the property is irreducible to the individual components of the system, in other words, it arises as a consequence of how elements interact in what we will argue is essentially a syntactic structure, not of the nature of the elements themselves. This is essential for our proposal, since the theory of how elements interact in linguistic derivations is precisely the theory of syntax, narrowing the scope of "syntax" to language, for expository purposes only.

The concept of self-organization is also independent of composing units. This means that, while the system as a whole may display a certain behavior (e.g., asymptotical behavior towards a point or an attractor), no individual in the system has consciousness of this global characteristic, which means that self-organization is not driven by a "leader" organism in biological systems or by a certain element present in a derivation in mathematical or linguistic structures. This means that we can only appreciate this tendency towards order if we, as observers, are (even if only theoretically, as in the case of social or population dynamics) outside the system. Moreover, the concept of self-organization is highly dependent of that of *time*: a set of elements initially distributed randomly adopts a structured configuration in a process that, for expository reasons, we will consider discrete (i.e., varying the T dimension step-by-step, T_x, T_{x+1}, and so on): since we will work with a generative operation applying successively to *n* objects, a continuous approach to the derivational diachrony would make the exposition confusing. Continuing with the characterization of self-organization, it is important to mention the proposal by Bak & Paczuski (1995), who summarize much of previous discussion (e.g., Gould, 1989), and introduce the concept of critical point (of major importance in chaos theory) in self-organization. Given a difference equation (a specific type of recurrence relation, recursively defining a sequence in which each term is a function of the previous one, quite in the line of the step-by-step derivational procedure we argue for), there is a critic value for a variable, which determines the arise of chaotic behavior in a system. For instance, in Feigenbaum's (1975) system, the binary-branching graph behaves chaotically after $r \approx 3.6$ in (1)

1) $f(x) = rx(1\text{-}x)$

The resulting graph is the following:

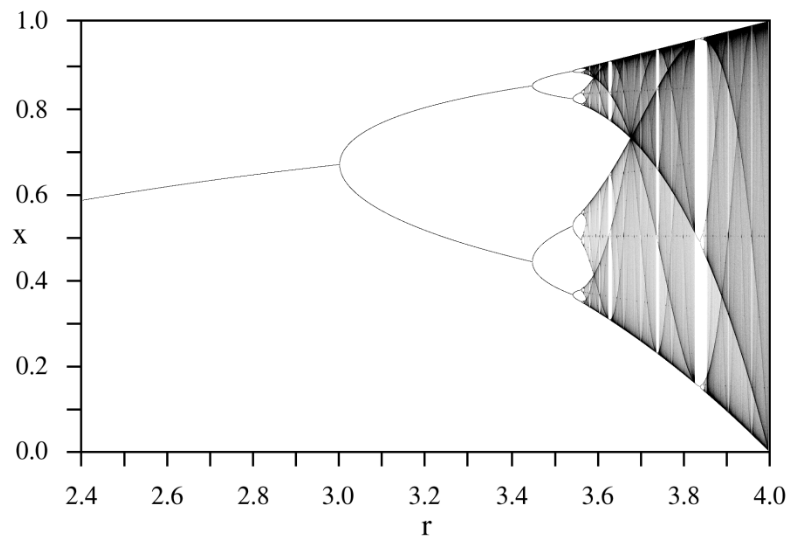


Figure I

Notice that there are non-periodical zones of binarity after chaos. This is to be born in mind: on the line of Uriagereka (2011) –although there are considerable differences between his approach and ours- we have characterized a linguistic derivation as a finite set of applications of a specified generative algorithm, in which entropy values fluctuate after each application (Krivochen, 2013a), tending towards minimization of entropy within each *cycle*[1], a concept we will briefly develop below.

[1] David Medeiros (p.c.) has commented at this respect that "My uninformed intuition strongly suggests that, *qua* natural system, it should rather maximize entropy. I had read something recently about extending this to the idea that natural systems tend to maximize *future* entropy, (which turns out to make different and better predictions in some domains)." We think this objection is too important to be left aside, even if we have had no access to the predictions Medeiros mentions. A summarized version of the extensive case we have made in Krivochen

These cycles of alternating entropy as we derive a well-formed formula in a formal system (in language, a sentence in a natural language L, abstracting performance factors solely because of methodology), we will argue, are closely connected to considerations of locality over dependencies, which rule, for instance, the interface-optimal derivational distance between an anaphoric element and its antecedent (as in 2), superiority effects in English Wh-interrogatives (in 3), and variations in quantifier scope depending on the closest argument (in 4), to mention but a few:

2) a. Mary_i likes a picture of herself_i
   b. Mary_i said [that Anna_j likes a picture of $\text{herself}_{*i/j}$]
3) a. Who wants what?
   b. *What who wants?
4) a. Every man loves a woman
   Logical Form: $\forall(x)\ \exists(y)$ (x is a man & y is a woman & x loves y)
   $\exists(x)\ \forall(y)$ (x is a man & y is a woman & x loves y)

As argued by transformationalist generativists and non-transformational generativists alike (see Patel-Grosz, 2012; Müller, 2011; Boeckx, 2008 on the one hand, and Stroik, 2009; Sag, 2007; Green, 2011 on the other, for recent examples of both positions), locality is a pervasive property of syntactic structures. In brief, the orthodox position has, in turn, two aspects: the *locality-as-impenetrability* concept of Chomsky (1986, 1999, 2008), according to which there are certain syntactic objects, defined beforehand, which are impenetrable to external operations (so-called "barriers" back in the '80s, now dubbed "phases"[2]); and the *locality-as-non-interveniency* proposal made by Rizzi (1990, 2009), which is best summarized by the Relativized Minimality Principle, formulated as follows (Rizzi, 2009: 162):

> "*…in a configuration like the following:*
>
> *. . . X. . . Z . . . Y. . .*
>
> *no local relation can hold between X and Y across an intervening element Z, if Z is of the same structural type, given the appropriate typology of elements and positions, as X.*"

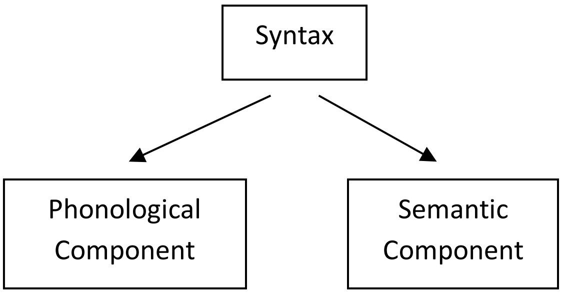
Needless to say, there are complications with both approaches. Chomsky's theory requires stipulative definitions of what constitutes an impenetrable object and what does not, which has been already challenged (e.g., by Uriagereka, 1999, who proposes to define local domains according to phonological / linearization requirements). Rizzi's theory requires a rich typology of elements and positions (something the author himself recognizes), which makes the theory inelegant and biologically implausible. Both share the characteristic of being syntacticocentric (in terms of Culicover & Jackendoff, 2005), which amounts to saying that the focus is set on the syntactic component, isolated substantively *and* methodologically from semantics and phonology, and

(2013a) would be as follows: Say we have a type-array {a, b, c, d}. The first derivational step is the most entropic, since any option is equally likely to enter the derivational workspace. Say {a} is selected. The derivational options are cut now, since not all combinations are legible by the semantic interface, which I think drives the derivation. In this sense, if Merge is semantically driven, it minimizes entropy in a local level, until we reach a derivational situation in which, again, all options are equally possible. There, we have maximum entropy, again, and incidentally, we can define phases *qua* periodical measurements of entropy (the interpretative interfaces accessing the syntactic workspace), as "cycles" with entropic peaks and sines. Our system, then, is not uniformly but *locally* "entropy-reducing". The notion of *local cycle* is of central importance in our model.

[2] See Boeckx & Grohmann (2004) on this issue, as the similarities between *barriers* and *phases* are too obvious to be left aside.

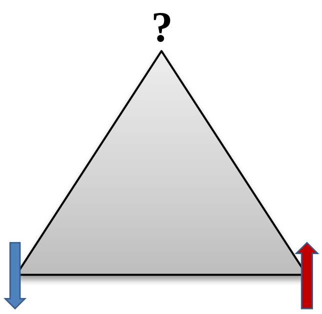
constraints on well-formed formulae are exclusively syntactic in nature. The syntactic component then handles (or, technically, "transfers") chunks of information (proper subsets of the overall derivation) to the external systems in charge of semantics (the so-called Conceptual-Intentional system C-I) and phonology (the Sensory-Motor system S-M), the directionality of this process being represented by arrows instead of simple lines in (5). The orthodox generative architecture for the language faculty can be schematized as follows:

5)

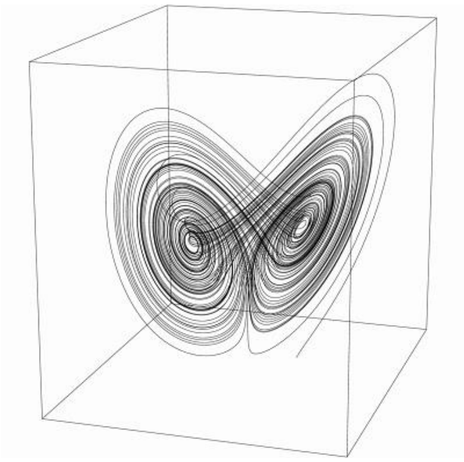
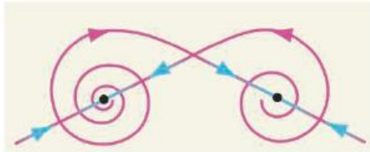


What is the role of dynamical frustrations in this discussion? So far we have been discussing some properties of dynamical systems, analyzed through difference equations. Binder (2008) claims that the main characteristic of dynamical systems (which sometimes appear to be very different in a surface level, take for example heartbeat rate and climatic conditions as examples) is that they display a fundamental tension between global and local tendencies, which is called a *dynamic frustration*. These frustrations arise, for example, in a triangle lattice under the condition that all three be antialigned (that is, aligned in an opposite direction) with respect to one another: three neighboring spins cannot be pairwise antialigned, and thus a frustration arises (Moesler & Ramirez, 2006: 25-26; Binder, 2008: 322). Let us graph the situation:

6)

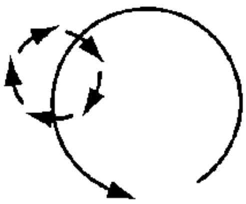


Binder goes even further, positing that a complex system where no frustration arises will "*either settle to equilibrium or grow without bounds*" (2008: 322). Equilibrium, in this case, is not *balance*, which could be, in principle, desirable: we are not referring to an optimal organization of matter or distribution of forces, but to complete lack of activity (for instance, a pendulum, which, after a while, stops moving altogether). Crucially, a system can display opposing tendencies at different scales: local and global tendencies may result in a "lattice triangle situation" like the one just graphed. A relevant example is the well-known Lorenz attractor (7a, b) (which describes the behavior of a chaotic system), where there are opposing clockwise and counter-clockwise tendencies in the 3-D phase space (7 b is taken from Binder, 2008: 322):

7) a)  b) 

In the 2-D figure (7 b) we can see opposing tendencies between “*stretching out and folding*”, in a resemblance of centripetal and centrifugal forces pulling the attractor in opposite directions. As the attractor “grows” in each dimension, centrifugal forces can be informally said to prevail. This kind of frustration, exemplified by chaotic systems, is called a *geometrical frustration*.

There is another kind of frustration, which arises when global and local tendencies are opposing in nature: so-called *scale frustration*. Binder’s example is a clockwise global tendency with local counter-clockwise cycles, as in (8):

8) 

As we have argued in Krivochen (2013b), this kind of frustration might be essential when considering the cognitive processes that take place in language processing, both production and interpretation. What is more, we have argued in that work, and will argue here (going deeper in the line of Uriagereka, 2012: Chapter 6), the concept of frustration is also of key importance when trying to situate language in relation to other cognitive capacities. If language is indeed a locally chaotic system[3], as put forth in Krivochen (2013a), then the *geometrical frustration* illustrated in (6) is relevant, insofar as the mathematics associated to a Lorenz attractor, or Feigenbaum’s differential equation could prove useful for modeling linguistic derivations. On a different scale, the interplay between different components in language (namely, syntax, semantics, and phonology), and also between language and other cognitive capacities (and the respective computational procedures underlying them) would require a model in line with the concept of *scale frustration*, to account for global and local effects in different components and their interplay (technically, their *interfaces*).

The notion of “scale” in frustration is essential for our argumentation, since we will work at first with two different kinds of frustrations, at different levels and each comprising local and global tendencies, and then try to unify them into a single kind of frustration.

[3] By “locally chaotic” we mean not only that the machinery is essentially derivational, but that the derivation, as it proceeds, step-by-step, displays an entropic behavior.

2. A frustrated mind

We will argue, following the line of previous works, that there are two kinds of frustrations at two different scales to be taken into account:

- *Architectural frustration*
- *Derivational frustration*

In the following subsections we will analyze each in some detail.

2.1 *Architectural frustration: quantum or Markovian?*

In Krivochen (2013b), somehow following Uriagereka (2012), we have put forth the hypothesis that there is a fundamental tension in the human mind: a global tendency towards quantum computation and an opposing, local tendency towards Markovian processes. What is more, the *locus* of Markovian processes can quite uniformly be found whenever symbolic structures are to be externalized (i.e., when the S-M system comes into play). This frustration, being pervasive to more than one mental capacity, is thus called *architectural frustration*, as it underlies the interplay between faculties. As such, it is wider in scope than the *derivational frustration*, belonging to a lower, or narrower scale.

Global quantum processes have been argued for since the late '40s, once the inadequacy of purely statistical models to account for mental computations was a well-installed research topic. As Stapp (2007: 52) points out, increasing interest in quantum models for "consciousness" has arisen since the publication of Penrose (1997), as well as Hameroff & Penrose (1996). Stapp (2009) himself proposes a model for "consciousness", as well as McFadden (2002) –although somehow more focused on cell biology than on the brain as a whole-, and Vitiello (2001). The Cognitive Revolution of the '50s, which had a great impact on theoretical linguistics, brought along a strong support for computational theories of the mind, and the formalism that outmatched the others was, by and large, Alan Turing's: to this day, there are Turing-computable models of the mind, and even a "Turing Program for Linguistic Theory" (see Watumull, 2012), based on the claim that cognition can be modeled uniformly within an unlimited-memory, recursively enumerable grammar (see Uriagereka, 2012, Chapter 6 for discussion). However, the quantum revolution that had taken place in the early decades of the 20th century had influenced part of the field of cognitive studies, and the idea that quantum effects are not just oddities at the Planck scale (ultimately, an idea stemming from the EPR paradox and Einstein's research on relativity) began to grow and develop. In this scenario, cooperation between physicists and brain scientists (cognitivists and neurologists) started around 1960, with the possibility of conceiving the brain as a many-body system: there are subsystems and their repeated complex interactions create quantum correlations.

Summarizing discussion from Krivochen (2013a, b), we characterize our take on the so-called *quantum human computer* as follows:

a. It is a computational system, which builds on the assumption that mental processes are derivational (see Culicover & Jackendoff, 2005, section 3.2 for discussion within linguistics). This means that, in order to get from a state α to a state β (where 'states' can be represented formally as symbolic 'strings', in the sense of Chomsky, 1956) there is a sequence of steps to follow. In transformational grammars TG, like orthodox Chomskyan theory, there are two kinds of such steps:

    - Structure building

- Structure mapping

Structure building is exemplified by means of External Merge, an operation that takes α and β, $\alpha \neq \beta$, and builds {K, {α, β}} (see Kitahara, 1997 for discussion). Both α and β are in this case taken from the Lexicon of the relevant (formal) language. Structure mapping involves tampering structure building, or, in other words, mapping a structure onto another via a rule. Internal Merge is an example, where either $\alpha \subset \beta$ (assuming α is a non-terminal) or $\beta \subset \alpha$ (assuming that β is a non-terminal). The process can be graphed as follows:

9) $\Sigma = \{K, \{\alpha, \beta\}\} \rightarrow \Sigma' = \{\alpha_i, \{K, \{\alpha_i, \beta\}\}$

In a non-transformational grammar (e.g., Lexical Functional Grammar, Head-Driven Phrase Structure Grammar, among others; see Borsley & Börjars, 2011 for an overview), there are only structure building operations, frequently associated to lexical properties of predicates, stored in the Lexicon. The main feature of such grammars is the absence of structure-to-structure mapping rules, otherwise known as *transformations* (e.g., Lasnik & Saito's 1984 *Affect-α*). In the case of a non-transformational model, as the one we have proposed in Krivochen (2012, 2013a) and Krivochen & Kosta (2013), Σ and Σ' are derived independently via structure building algorithms, optimally reducible to a single, *n*-ary concatenation function:

10) *Concatenation* defines a *chain* of coordinates in *n*-dimensional generative workspaces W of the form $\{(x, y, z\ldots n) \subset W_X, \ldots (x, y, z\ldots n) \subset W_Y, \ldots (x, y, z\ldots n) \subset W_n\}$.

b. It builds on the assumption that derivations create, step-by-step, structured representations using symbolic representations regardless their inner complexity, only identified via their coordinates in the mental workspace, a similar concept to that of "working memory" (Baddeley, 2003), or a working bench in which operations apply (which is why we called them "generative" workpaces in (10), in the sense that it is there that representations "generate"), driven by different needs (we will focus on semantic requirements, but this does not imply, at all, that those are the only requirements to be taken into account). Those representations are evaluated by interpretative systems IS interfacing with the workspace in which the generator (GEN) algorithm (the operation that builds structure from atomic units, the *concatenation* algorithm in (8)) applies. In the relevant case, GEN = *n*-ary *concatenation* and IS (Interface System) = phonology / semantics. Under Radically Minimalist assumptions, evaluation of symbolic structure takes place also step-by-step (after each application of *concatenation*), resulting in the following derivational dynamics:

11) Concatenate $(\alpha, \beta, \ldots n) = \{\alpha, \beta, \ldots n\}$
Analyze_{IS} {α, β} [is {α, β} fully interpretable by IS?]
Transfer {α, β} to IS if Analyze_{IS} results in convergence at IS)

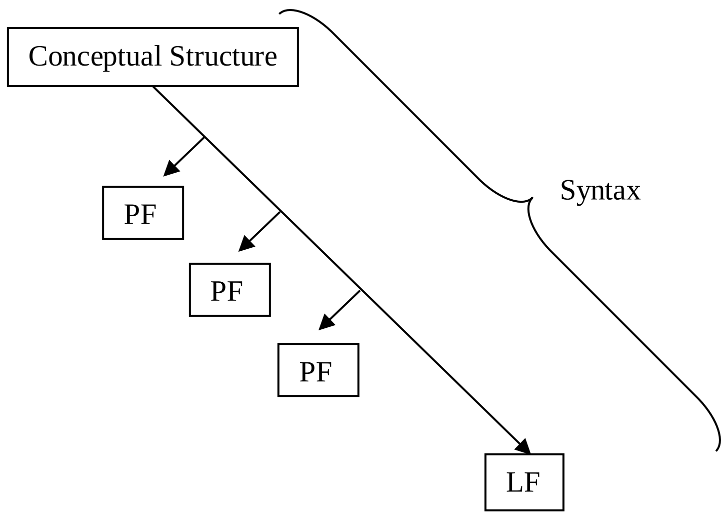
Given IS = Phon & Sem, Transfer ({α, β}) is referred to as *Spell-Out* (Chomsky, 1995; Uriagereka, 1998, 2012). If evaluation by IS need not be simultaneous (which we take as the null hypothesis, under modular assumptions), then transferred objects to Phon and Sem need not coincide. The tension between the *Analyze* conditions each IS imposes objects results, we will argue, in a *frustration* in the technical sense specified above.

c. It allows any object O of arbitrary complexity to comprise, before interpretation (i.e., transfer to the interpretative systems, whichever they are), $n > 1$ states at once, what is customarily called "the ψ-state". n collapses to one of the possible outcomes *at the interpretative levels, not before*. This is particularly visible when considering the systems of *category*, *thematic interpretation*, and *case* (affecting either sortal or eventive entities), neither of which is fixed before entering a particular derivation, but are both interpretations of *local* relations between syntactic constituents, in the sense of locality discussed above.

d. It is blind to the characteristics of the manipulated objects

The aforementioned assumptions are related to (even if in a non-necessary way) a proposal about the architecture of the cognitive system underlying language production and comprehension, and the mathematics necessary to model it. The architecture we assume is the following, where cycles are PF-driven, as in Uriagereka's Multiple Spell-Out model, but the overall system is LF-driven, thus generating a tension:

12)



The QHC as a program (with all the theories it comprises, take Hameroff & Penrose's 1996 OrchOR model as an example, and our own proposal as another) has, in our opinion, some advantages to be taken into account for linguistic theory: to begin with, the simplification of the lexicon. If an element in the lexicon remains in a ψ-state prior to its insertion in a derivational context via *concatenation*, then we eliminate all kinds of diacritics (including categorial, case, theta, φ- (person / number), Time, Aspect, and Modality specifications), which are hard to avoid in lexicalist theories (due to the Lexical Integrity Principle, which asserts the opacity of lexical representations for syntactic operations thus separating the domains of the Lexicon and the "narrow syntax", see Ackerman et. al., 2011; and Carruthers, 2006: 5-7 for some discussion related to the concept of *inaccessibility*, which applies to the lexicalist Lexicon) as well as in late-phonology-insertion theories like Distributed Morphology (which "distributes" lexical information in three components, or "Lists" A, B, and C; comprising formal features, phonological matrices, and encyclopedic knowledge respectively), where specific elements dubbed *categorizers* are needed to specify the categorial status of a root, and thus its distribution and selectional properties (Halle & Marantz, 1993). The "computational system" is also drastically simplified: on the one hand, the 2-D limitation LCA-compatible X' theory imposes is eliminated, as the model is semantically oriented, and there are no proofs that semantic structures are indeed Markovian, nor theoretical reasons (beyond excessive simplification) to assume a strong uniformity among different cognitive domains. Pre-defined domains are also eliminated (Cf. Chomskyan phases and, to a lesser extent, Grohmann's Prolific Domains, which delimit relevant derivational chunks for the application of operations), as the EVAL function (our *analyze*) applies in an extremely local way, as made explicit in (9), without it implying extremely local *optimization* (Cf. Heck & Müller, 2007), as *optimality* is, we argue, a relational notion, not an imposed condition over structure. What is more, as has been discussed by other authors, referred to above, there are strong indicators of quantum effects beyond the Planck scale: from the consciousness model by Penrose & Hameroff to the pure neurologically based proposal of McFadden, with the linguistic (syntactic-semantic and pragmatic) considerations we have made in previous works, to be summarized here. This means that, globally considered, it is a plausible hypothesis to claim that human cognition has the potential to work on *n*-dimensional, quantum bases. The scale is, as we said, essential to this claim. While global computations seem to display quantum properties (multidimensionality, long-distance dependencies not necessarily cyclic –analogous to quantum entanglement effects-, among others), local processes are often better expressed by simpler models, sometimes, the only way to explain or model certain processes is to assume there is another kind of computational procedure applying, otherwise, we would be assigning a certain representation "more structure" than it really has (for example, while phrase structure grammars are adequate to capture the properties of adjectival modification and scope, they are too powerful to deal with simple adjective iteration, when there is no scope relation between the terms involved). This kind of problem arises at each derivational point where Transfer (PF) applies. Taking into account Isardi & Raimy (in press), *n*-dimensional phrase markers must undergo a dynamic process of Markovization, which we have called Spell-Out. They distinguish three "modules" of linearization, with different characteristics (Isardi & Raimy, in press: 3):

13) ***Module*** ***Characteristics***

Narrow syntax	hierarchy, no linear order, no phonological content
LINEARIZATION-1 = **Immobilization**	
Morphosyntax	hierarchy, adjacency, no phonological content
LINEARIZATION-2 = **Vocabulary Insertion**	
Morphophonology	no hierarchy, directed graph, phonological content
LINEARIZATION-3 = **Serialization**	
Phonology	no hierarchy, linear order, phonological string

Arguably, the *morphophonological module* and the *phonological module* are Markovian in nature, since there is no hierarchy in linearized strings. Between *morphosyntax* and *morphophonology* there must exist a dimensional flattening (in the terms of Krivochen, 2012b) algorithm, which transforms a hierarchical structure into a flat structure, without imposing extra structure, but following a strict *conservation principle* (Krivochen, 2011, see also Lasnk & Uriagereka, 2005 for discussion of conservation under orthodox assumptions). A phrase structure approach to vocabulary insertion (assuming a separationist approach in which terminals receive phonological matrices at Spell-Out, and not before, see Halle & Marantz, 1993 for discussion and a first "late-insertion" proposal) and linearization, even though possible, is undesirable if a simpler solution is available. Taking into consideration the architecture sketched in (12), this architectural frustration between global quantum processes and local Markovian processes takes place at each point of contact between the CS-LF arrow and the PF-leading arrows. More generally, and even if there is no language involved, conceptual structures, with their underspecification and *n*-dimensional character, are better expressed by means of non-linear mathematical models, including quantum computation. However, quantum computation seems inadequate for some tasks, such as linearization (regardless whether we are discussing language, music, or some other form of structure externalization), which flattens phrases (in the technical, symbolist sense) to strings.

Needless to say, the fact that the *rules* that generate (in the strong sense) a string or a structure are linear does not mean that the generated object is actually Markovian. As Belk & Neeleman (2013) point out,

> "(…) *since the early 1980s, there has been an attempt in syntactic theory to abandon rules that have a linear component in favour of rules that only refer to dominance and labeling. Part of the motivation for this trend is the pervasive necessity of reference to structure in the description of linguistic phenomena.*" (2013: 1)

When we refer to the quantum of Markovian character of a representation, or a derivation (more generally, any object of inquiry), we are hypothesizing about *the object itself*, regardless of the character of the formal apparatus used to model the object. An L-grammar, for instance (linear in character), can be used to generate non-linear (and perhaps even non Turing-computable) sequences, if combined with an appropriate theory of node multidominance, just to give an example. We will return to this point below. It seems that pure quantum or Markovian models are inherently insufficient, not because of limitations of the models themselves, but because of the characteristics of the objects they model. Here we have our architectural frustration.

2.2 *Derivational Frustration: Semantic or Phonological Preeminence?*

The architecture in (12) makes a strong statement with respect to the status of interfaces, which in turn might be interpreted as a prediction: semantics structures the linguistic computational system, FLN in Hauser, Chomsky & Fitch's (2002) (HCF hitherto) terms. However, in opposition to HCF, we do not claim that *concatenation* is language specific: conceptual structures, which might or might not be linguistically instantiated, are structured symbolic representations, therefore syntactic in a strict sense. The conceptual structure we posit, following the line of linguists like Jackendoff (1983, 2002, 2010)[4], Culicover & Jackendoff (2005), and the sense in which D-Structure is interpreted in Uriagereka (2012), is syntactically assembled, displaying complexity, recursion, and other formal properties of syntactic structure. Moss et. al. (2007) and Taylor et. al. (2011) propose a (cognitive-neurological) model for conceptual structure, which is focused on the inner structure of "concepts" (what some linguists would call *roots*). The conceptual structure model proposed by Taylor et. al. (2011) differs from ours insofar as they take the word (or, rather, the "concept") already formed, whereas we consider that the distinctive features they require for object identification (what we would call "reference", from a semantic-linguistic point of view) are not part of the root itself, but are actually provided by procedural material that limits the intensional / extensional scope of the semantic substance, pre-linguistic and possibly universal, conveyed by the root alone.

[4] The following quotation is eloquent at this respect: "*According to Jackendoff, semantic structures (i.e. the semantic content in the mental lexicon) are simply a subset of conceptual structures which can be verbally expressed"* (Moss, et. al. 2007). However, contrarily to Jackendoff, we think that the set of possible conceptual structures properly contains the set of *verbally* expressable structures, because of PF-limitations partly due to its Markovian character.

We pursue a complementary model, focused on how those "concepts" are manipulated by syntactic means, to form structures that might, or might not, be expressed linguistically (but, for instance, through action). This implies that the elements manipulated to create conceptual structures (in the more complex sense we talk about) must be underspecified enough to be manipulated by more than one system. We agree with the claim in Caramazza & Mahon (2006) that conceptual knowledge must exist independently of the modality-specific input and output systems (e.g., perceptual and articulatory systems). The organization of both levels is assumed to be determined innately, and enriched with evolutionarily relevant conceptual categories according to which to organize information. In a more narrow linguistic sense, Moss et. al. (2007) claim that

> (…) *conceptual representations form an interface between lexical information and other domains such as sensory and motor systems. This function introduces several constraints on the nature of these representations; irrespective of their content, they must be in a format that is readily accessible by both a range of linguistic and non-linguistic modalities of input and output, they must permit processing rapid enough to support on-line production and comprehension of meaningful speech at a rate of several words per second and to support rapid and appropriate motor responses to meaningful sensory stimuli in the environment, and they must enable flexibility of meaning across different contexts of use* (…)

In Krivochen (2011, 2012a, b, 2013a, b) we have stressed the issue of *format* as a *sine qua non* condition for *n*-objects to enter a dependency relation (for instance, via *concatenation*). At the level of semantic structuring, this seems particularly relevant, insofar as the result of the computations at C-I is to be readable by more than a single system. The caveat with respect to the relation between lexical information and other systems is essential here: conceptual structure does not equate to lexical structure, rather, CS is ontologically and derivationally prior to lexical structure. The CS-lexicon interface is only one of the interfaces CS is conditioned by, and in turn, CS is only part of lexical information (which would arguably include categorial and distributional information in lexicalist models, both of which are absent in CS). A direct interface[5] between CS and "motor systems", if these are not directly connected to speech organs, could result in an action rather than in a verbal externalization (which, by the way, would eliminate the need for periodical Markovian cycles). Without entering a complex network of systems and interfaces like the one proposed by Jackendoff (2002, 2010) and his *parallel structure*, where linking rules are indispensable (but quite anti-economical); or HPSG's networks (Green, 2011), to mention but a few, it seems that a *multiple interface* approach to CS is, at the very least, hard to avoid.

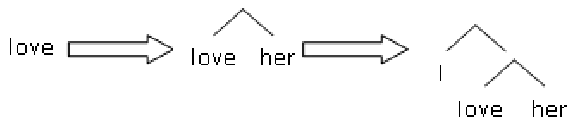
This stance is strongly aligned with *componential* models of meaning, which decompose complex meaning in more basic elements (in our case, roots and procedural elements indicating the relevant system how to process the relations between roots, quite in the line of Relevance Theory, see Sperber & Wilson, 1995; Wilson & Sperber, 2004), supported by psycholinguistic literature at the lexical level; but extending it beyond the concept to analyze how these are syntactically related. This kind of conceptual structure is what, we propose, drives a linguistic derivation in a global sense, determining what is to be concatenated with what in order to convey the information of the CS in the less entropic possible way. The choice of elements to derive with, for instance (what is called an *array* or *numeration* in orthodox Minimalism), can be seen as a function of CS, insofar as the optimal scenario

[5] An important note is in order: "direct" means that there is no third system mediating the connection, not that the interface is "transparent", insofar as no two systems manipulate the same kind of information in the same format. Transfer, understood as information flow between systems, is always entropic. An important point a theory should address, in our opinion, is *how* entropic an interface is, and *to what extent* this entropy is countered by the organization of the system itself.

would seem to be that in which only the minimal number of elements *required* to convey CS is the less entropic way possible are selected from the Lexicon, regardless (at this point) of their materialization. While it would be at least odd to claim that a linguistic derivation starts with a phonological matrix, it seems to us to make sense to claim that it starts off with an *intention*, in the form of a complex CS.

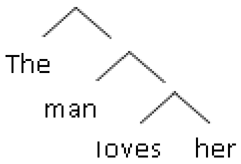
However, a further variable is to be taken into account. If the structure is to be materialized (i.e., Spelled-Out), then the symbolic structures generated by *concatenation* must be not only materializable by virtue of their *format*, but also of their *content*. This means that Spell-Out cannot linearize certain phrase markers (as argued by Uriagereka, 1999, 2012) because they fail to comply with a structural requirement (a non-monotonic phrase marker), but it is also possible that a terminal node cannot be provided with a phonological exponent because, in a certain natural language NL, there is no phonological exponent that corresponds to the information conveyed by a certain terminal or set of terminals. These situations are exemplified below (arrows signal successive derivational steps):

14) a.



b. Spell-Out input: [I [love [her]]]

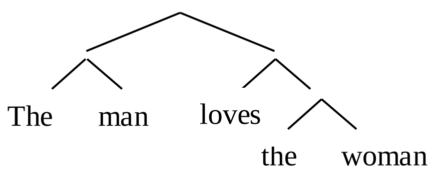
15) a.



b. Spell-Out input: *[The [man [loves [her]]]]

As we can see, the fail in the phrase marker (14 a) is that [the man] is not treated as a constituent, either semantically or phonologically (e.g., in unmarked contexts, neither [the] nor [man] can be prominent by themselves, whereas the whole constituent could be prominent if the thematic position were relevant for some reason). For all syntax cares, being a component-neutral algorithm, it is a perfectly plausible phrase marker, but the semantic scope of the determiner over the noun is not captured. There is a hierarchy that is not captured via pure monotonic concatenation, whose limits, as Uriagereka (2012: 53) suggests, are those of a finite-state grammar (see also Kartunnen & Beesley, 2005 for an overview of finite state models of morpho-phonological properties). Conversely, if syntactic complexity increases, via non-monotonic concatenation (involving two non-terminals), Spell-Out must apply in a multiple fashion (Uriagereka, 1999/2002):

16) a.



b. Spell-Out pattern: [[The man] [loves [the woman]]]

Since the phrase marker goes beyond the limits of Markovian dependencies, Spell-Out applies to each Markovian-compatible sub-phrase marker (in this case, [the man] and [loves the woman], each assembled *separately* via monotonic concatenation in parallel workspaces, see Krivochen, 2012b), thus chunking the derivation according to local PF requirements. The *parallel workspace* theory partly derives from the so-called "Finite State limit on phrase structure", and, partly following –and expanding on- Isardi & Raimy (in press), it is a condition over symbolic representations, at a *local* level, phrase by phrase.

Even at a smaller scale, let us say, "word-level", morpho-phonological conditions can influence the derivational procedure, provided that we work with a system that allows dynamic access from the C-I and S-M systems to the working area. Single concept-level is the focus of attention of conceptual approaches like Moss et. al.'s (1997) Conceptual Structure Account, but here we will not make a concept-word correlation (as somehow suggested by Moss et. al., 2007): we will rather focus on what makes a word, independently of the concept it instantiates. As has been argued by linguists for decades now (see Di Sciullo & Williams, 1987; Halle & Marantz, 1993; Hale & Keyser, 2002; Starke, 2011; Acedo-Matellán, 2010; Ackerman et. al. 2011, for a variety of views, within different frameworks, often not mutually compatible), a phonological word does not always correspond to a single terminal in a Markovian (i.e., finite state) structure. Assuming that all terminals in the structure below convey some interpretable information (i.e., they are not "radically empty", cf. De Belder & van Craenembroeck, 2011), phonological insertion could target more than a single node. For example, Spanish morpheme [-ba] comprises Person (1^{st} or 3^{rd}), number (singular), Tense (past), Aspect (imperfective), and Modality (realis). Some languages, like Latin, allow even diathesis to be grouped with these nodes, such that so-called "passive voice" is expressed in a synthetic way, instead of English or Spanish analytical (periphrastic) mechanism (e.g., while [amo] is 1^{st} person, singular, present, realis, active; [amor] comprises equal person, number, temporal, aspectual, and modal features, but *passive* voice). The procedure via which several terminals are materialized by a single morpho-phonological piece is called *fusion* in Distributed Morphology (see Halle & Marantz, 1993 for details).

In close relation to this, in past works we have proposed that, if the interfaces have access to the working space, then (*ceteris paribus*) they can condition at least part of the succession of concatenations there performed. It has been argued that terminals can be merged together, via *incorporation*, a sub-type of so-called *head-to-head movement*, in the traditional X-bar theoretical framework (see Baker, 1988 for extensive discussion). In this operation, two terminals, α and β, are joined together to form a single complex terminal, known as a X^0_{max} because it is neither a terminal in the strict sense (thus, not an X^0) nor a fully-fledged phrase (thus, not an X_{max} or an XP). We have hypothesized that feature grouping (where "features" could be interpreted in the sense of Taylor et. al., 2011, but including eventive-related features, like [manner], [motion], [direction], etc.) in a terminal, or, more generally, to be Spelled-Out (if we consider that materialization can target more than a single terminal at a time, somehow on the line of Nanosyntax, see Starke, 2011) is locally conditioned by the possibility to actually insert a phonological matrix there. The principle we proposed determining the possibility of *fusion* is the following (adapted from Krivochen, 2012a: 103):

17) *Morpheme formation constraint*: syntactic mechanisms do not group features in a terminal node if there is no vocabulary item VI specified enough to be inserted in that node and Spell-Out the features there present.

For example, Spanish does not allow [manner] incorporation onto [motion], which we explain in our model by saying that there is no VI that can Spell-Out both features. However, it allows [direction] to incorporate onto [motion], whereas English coinage behaves the other way around[6]. Examples like these abound in typological literature, and this particular phenomenon has been studied thoroughly by Mateu Fontanals (2002). This is, we think, a clear PF-constraint, acting at a local level. The tension between global semantic tendencies and more local morpho-phonological cycles is clear.

3. Conclusion: Unifying Frustrations

Throughout this paper, we have tried to keep the two frustrations we claim exist in the human mind separate, since they are actually independent hypotheses. One could claim that the human mind displays a quantum-Markovian tension without adhering to the theory that such a tension has any correlate to the semantics-phonology tension present in human language, and there is no logical inconsistency in that position. As it might have slipped throughout the paper, also, we adhere to both hypotheses and, what is more, we claim that they can be unified in a single frustration, displaying varieties of scale but not of nature. The literature on quantum models of the mind (e.g., Stapp, 2009; Penrose, 1997; Vitiello, 2001, among others) tends to make a generalization of uniformity about the quantum nature of mental processes, which makes their proposals vulnerable to Litt et. al.'s (2006: 1-2) objection:

> "*We argue, however, that explaining brain function by appeal to quantum mechanics is akin to explaining bird flight by appeal to atomic bonding characteristics. The structures of all bird wings do involve atomic bonding properties that are correlated with the kinds of materials in bird wings: most wing feathers are made of keratin, which has specific bonding properties. Nevertheless, everything we might want to explain about wing function can be stated independently of this atomic structure. Geometry, stiffness, and strength are much more relevant to the explanatory target of flight, even though atomic bonding properties may give rise to specific geometric and tensile properties. Explaining how birds fly simply does not require specifying how atoms bond in feathers.*"

Our proposal of co-existence of quantum and Markovian processes escapes this objection (as does, for example, Hameroff's 2007 mixed proposal, a reaction to Litt et. al.'s paper), which does not take into account the concept of *scale*. In an appropriate level of abstraction, it might very well be relevant how protein bonds configure structures that allow physiological processes at higher levels. Just the same, while describing the structure of a relative clause in generative terms might not require quantum considerations, we have seen that there is evidence for at least pursue the possibility that quantum processes beyond the Planck scale are manifested in mental computations in general, and linguistic derivations in particular; just as much as Markovian and finite state grammars are indispensable to explain the semantic / phonological properties of certain structures (like iteration, see Uriagereka, 2008, Chapter 6; and context-sensitive morpho-phonological rules, see Kartunnen & Beesley, 2005).

Provided that semantic/conceptual structures display quantum properties, and linearization of such structures is plausibly conceptualized as cyclic Markovization (Isardi & Raimy, in press), the unification of both frustrations is, while not obvious, quite straightforward. Taking into account the

[6] While it is true that the English lexicon does contain words like [enter] and [exit], which display both [motion] and [direction], they are actually Latin roots, not Germanic roots. Thus, both [enter] and [exit] are originally compounds of Latin [ire] (go) plus a preposition indicating direction (in+ire; ex+ire).

architecture depicted in (10), it might very well be true that "*frustration mechanisms articulate representations*" (Uriagereka, 2012: 248), but we do not agree that those representations fall within the Chomsky hierarchy. The explicit introduction of quantum and non-linear processes (the latter, for instance, to account for cyclicity effects, as in Figure I) goes beyond the limits of the Chomsky hierarchy, and we have argued in Krivochen (2013b) that the hierarchical taxonomy of formal languages is to be deeply revisited, if not altogether abandoned: while it is true that higher-level languages can express, or generate, everything lower-level languages can, and more; it is also true that most of the times this implies assigning extra-structure to the representation, an unjustified step, as Lasnik (2011) points out regarding the syntactic representation of iteration and the inadequacy of binary-branched X-bar theory for such structures.

The program we have presented in this paper is clear: language displays global semantic tendencies, quantum in nature; derivations being semantically driven. At a more local level, however, morpho-phonological requirements determine the existence of cycles, which are also a characteristic of chaotic systems, as we saw Figure I. At each derivational point, there is a tension between global conservation semantic tendencies and periodical morpho-phonological transfer points, never to be solved in *equilibrium* (in Binder's 2008 terms) as it keeps the derivation going. Future research will determine if this tension is actually resolved by the system in the most economical way possible given glocal and local requirements, the result thus being an optimal externalized expression of propositional content. This has enormous impact for theses of optimality of the design of mental faculties (Chomsky, 2005; Brody, 2003, among many others), since the optimal resolution of the frustration at each derivational point, which would yield an optimal output, does not necessarily entail "perfection" in the design of the mental faculty (or faculties) that produces that output. The fact that a system can, as we think language does, solve its inherent PF-LF frustration in an optimal way, does not mean that the system is, in any relevant way, "perfect". While the notion of optimality can be defined unambiguously, design perfection is relative to a system, a function, and an evolutionary trait (see Kinsella, 2009 for discussion). Only the belief that evolution is driven by "virtual conceptual necessity" can lead to the claim that optimality in the output implies perfection in the generative procedure. The output (π, λ) (π = Phon; λ = Sem, a pairing of form and meaning), in other words, the result of the resolution of the PF-LF frustration we have been analyzing, is "optimal" *iff* (from Jäger & Blutner, 2000: 21)*:*

18) $(\pi, \lambda) \in$ GEN [the set of formulae that a given algorithm, like *concatenation* can generate]
    There is no optimal (π', λ) such that $(\pi', \lambda) <$ [is ranked higher than] (π, λ), and
    There is no optimal (π, λ') such that $(\pi, \lambda') < (\pi, \lambda)$

Whereas this definition can be challenged, it has been developed extensively within formal Optimality Theoretic frameworks. No such explicit development has been provided in favor of the "perfection argument" in mental faculties. As prospects for future research, we propose to redefine optimality taking into account the notion of *frustration,* and how the essential tensions between systems are solved; and revisit the notion of perfection of a system based on the optimality of the output. We think that a mixed, quantum and Markovian model like the one proposed here is a good tool for the job, although, needless to say, not the only one.

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