AS
Acta Semiotica
II, 4, 2022
DOI 10.23925/2763-700X.2022n4.60285
Ouvertures théoriques

From Continuity to Rhythm II : Adjustment and Entrainment

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Introduction

This work is the second part of the article "From Continuity to Rhythm", where I set out to define rhythm as a semiotic concept[1]. The motivation was Victoria Santa Cruz's abstract concept of Rhythm as an organiser that integrates different units into larger wholes and that is the principle behind all becoming[2]. However, the formal point of departure was the notion of continuity proposed by Eric Landowski as a founding category of his semiotics of interaction[3]. Drawing from the conceptual framework developed in the first paper, this work establishes a relation between the semiotic concept of *adjustment* proposed by Landowski, and *entrainment*, a concept widely deployed in scientific research on music[4]. The

1 *Acta Semiotica*, II, 3, 2022, pp. 79-97. Henceforth, when rhythm is construed as a semiotic concept it is spelled as "Rhythm", with a capital "R".

2 V. Santa Cruz, *Ritmo : El Eterno Organizador*, Lima, Petróleos del Perú, 2004.

3 Cf. *Pasiones sin nombre* (2004), Lima, Fondo editorial Universidad de Lima, 2018, pp. 63-69 ; *Interacciones arriesgadas* (2005), Lima, Fondo editorial Universidad de Lima, 2009, pp. 14-15, 81.

4 Cf. P. Vuilleumier and T. Wiebke, "Music and emotions : from enchantment to entrainment", *Annals* of the New York Academy of Sciences, 1337, 1, 2015 ; M. Clayton, R. Sager, W. Udo, "In time with the music : the concept of entrainment and its significance for ethnomusicology", *European meetings in ethnomusicology*, Romanian Society for Ethnomusicology, vol. 11, 2005 ; A. Tierney and N. Kraus, "Neural entrainment to the rhythmic structure of music", *Journal of Cognitive Neuroscience*, 27, 2, 2015.

end result is a general semiotic definition of entrainment that yields a flexible semiotic definition of Rhythm.

In "From Continuity to Rhythm" I analysed the opposition between continuity and discontinuity in terms of three oppositions : self-identity *vs* difference, unity *vs* diversity and determinism *vs* randomness. In the conclusions I suggested that Rhythm could be construed as "a certain level of Harmony" within a system or set of elements where entrainment acts as "the unifying mechanism"[5]. This definition will be reviewed critically in this work. In order to do so, this paper sets out to explain *entrainment*, relating it to Landowski's notion of *adjustment*. In order to establish this relation I recur to feedback loops in an input-ouput process approach, often deployed in control engineering and computer science. Beyond entrainment and adjustment as specific mechanisms, however, lies the view of Rhythm as intrinsically dynamic. While adjustment and entrainment are key to this feature, I shall first address periodicity. The outcome will be a definition of Rhythm where periodicity, entrainment, adjustment and feedback are interrelated.

1. Continuity as periodicity

Landowski associates the continuous with a monotonous succession[6]. In this section I would like to formalise this view recurring to the notion of *periodicity*, deployed widely in mathematics, physics and engineering[7]. A function or signal is periodic if it repeats itself identically after a given period of time.

More formally, if the time-varying signal $y(t)$ is periodic, then it is the case that $y(t)=y(t+T)$ where T is the period of signal y, and t refers to time. For example, if a spinning wheel takes half a second to make a full turn, then we say that its motion is periodic and that the period T is half a second. Although this definition refers to time, t could refer to space as well, or any other relevant variable. Periodicity in space (i.e., painted patterns that repeat identically) can be seen in the ceilings of many cathedrals, for example.

For there to be periodicity there must be repetition. Ideally, repetition in periodicity occurs an infinite number of times and in addition it occurs at perfectly equidistant time intervals (with a value of T). These conditions apply to discrete periodic sequences as well. E.g., the sequence "AAA..." can be said to be periodical, even though there is no direct time reference, since we can say that "A" repeats identically every one character. Therefore, the period of the sequence is one. The sequence "ABABAB..." is also periodic, with a period of two characters. The definition of periodicity allows us to interpret Landowski's notion of continuity, in the sense of a monotonous succession, as a periodic se-

5 « From Continuity to Rhythm », *art. cit.*, p. 95.

6 *Pasiones sin nombre, op. cit.*, p. 64.

7 See for instance E.W. Weisstein, "Periodic Function", MathWorld-A Wolfram Web Resource (https://mathworld.wolfram.com/PeriodicFunction.html).

quence or signal that can be either continuous (the spinning wheel) or discrete (the "AAA..." sequence).

Periodicity can be placed in opposition to singularity ; i.e., to events or patterns that happen once. The relation between both is illustrated in the semiotic square in Figure 1. The contradictory of the periodic, is non-periodic infinite repetition. The contradictory of the singular is something that happens at least twice, i.e., non-periodic finite repetition. Both periodicity and singularity can be derived from the notion of infinite repetition — constraining repetitions to be equidistant yields periodicity, constraining infinite repetition on number yields singularity.

The periodic is uncohesive because any of its cycles is identical to any other. In contrast, a singularity is maximally cohesive, since it refers to a non-repeatable unity.

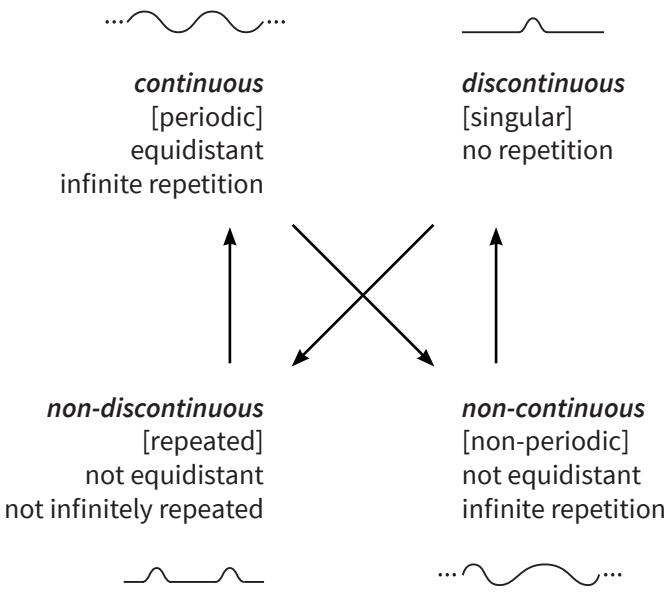

Figure 1. Continuity *vs* discontinuity as periodic *vs* singular.

What is the relation between periodicity and the semiotic concept of Rhythm this work is after ? Thinking of periodicity introduces a point of view that does not stem from Harmony. The latter deals with identity and difference, that is, with diversity compensated by unity. However, it does not explicitly consider repetition nor the structures that repetitions may form in virtue of their number or of their distance to each other. Repetition is interesting in the ontological sense, for it considers the token of a type insofar it is *realised* rather than *virtual*. That is, it has to do with something that actually *is* repeated rather than with something that *can* be repeated. As Figure 2 shows, interesting geometrical patterns emerge from only two types cleverly arranged and repeated. Comparing the starting point (two unrelated different shapes) to the resulting pattern as a whole, we can say the latter is more Harmonious. In this case the unifying

force consists of the identical repetition and placement of the shapes and of their periodic arrangement. In addition, the superposition of the array of squares and circles is more Harmonious than each array taken separately, as it is more diverse. Although the resulting pattern is composed of only two shapes, a third shape emerges at the centre of the squares due to the white space left by the orange circles.

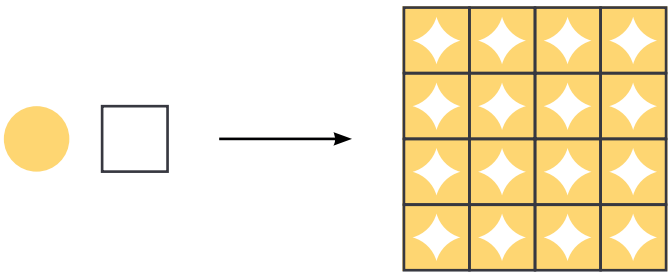

Figure 2. Combination of periodic repetition of a square and a circle to form a more complex pattern.

An example of combining singularity and periodicity can be playing a melody together with an identically repeating rhythmic pattern. Even if every bar in the rhythmic pattern is the same as the one before, the position of a given bar within a melody makes it possible to distinguish them. Hence, melody grants cohesion to the whole (melody + pattern). Furthermore, percussive rhythmic patterns are rarely played identically throughout a whole song. Often, variations are introduced to mark the end of a phrase or section or even to react to the rhythm of the melody. These variations that result in the segmentation of the totality into units (e.g., phrases and sections) will also grant the song its cohesiveness.

Combining periodicity with singularity can imply taking a singular pattern, repeating it periodically and modifying or *modulating* some of its repetitions in such a way so as to give a feeling of something rhythmic that escapes monotony and uncohesiveness. An example is the interior side of the dome of the Sheikh Lotf-Allah mosque in Isfahan[8]. Modulation allows for a number of possibilities and can also be related to the competencies of an actant, as explained in the next section.

2. Revisiting determinism *vs* randomness

In this section we revisit the opposition /continuous *vs* discontinuous/ expressed in terms of /determinism *vs* randomness/. This opposition will lead us to Greimas's notion of manipulation, to Landowski's syntax of adjustment and to entrainment.

The opposition /deterministic *vs* purely random/ can be analysed according to the semiotic square in Figure 3. The deterministic regime yields an output, a

8 See https://es.m.wikipedia.org/wiki/Archivo:Isfahan_Lotfollah_mosque_ceiling_symmetric.jpg.

set of utterances, relying on fixed production rules — e.g., the stream {A,B,C, ...} has the rule of printing out the letter of the alphabet in ascending order. The set of production rules that yield the output are henceforth referred to as the *system*. The purely random is an abstraction that is impossible to generate. The reason is that it is impossible to produce a sequence of numbers, letters or utterances where there is no relation between any of these elements to any other. Due to the absolute lack of relation present in randomness, the purely random has no system, only utterances. The non-relation of elements is represented in Figure 3 as the stream {B, 5, F, F, N, ...}.

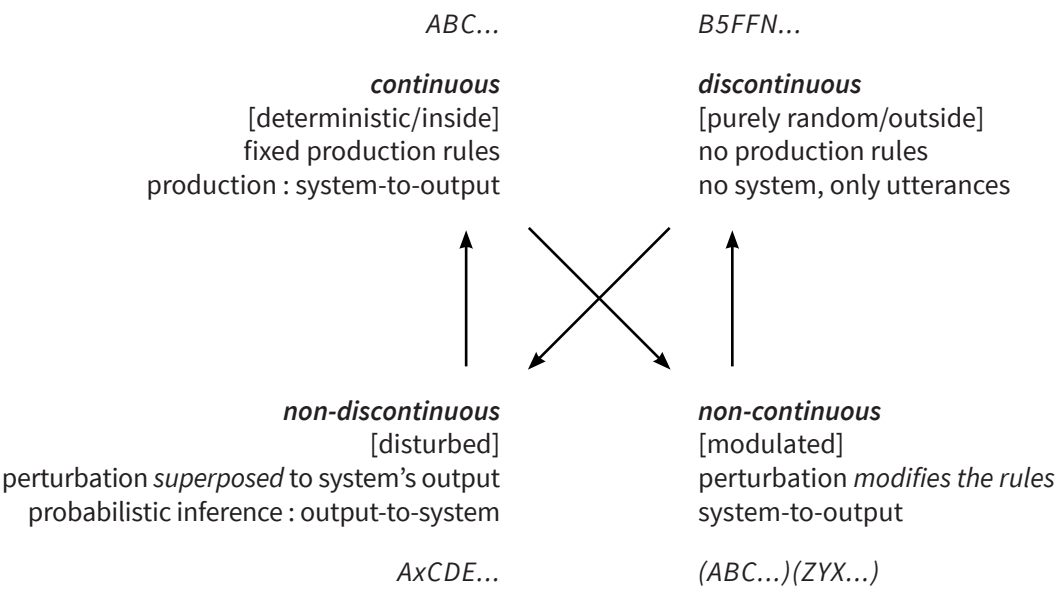

Figure 3. Semiotic square for the opposition continuous *vs* discontinuous in terms of the opposition deterministic *vs* purely random (cf. "From Continuity...", *art. cit.*, p. 92).

The *disturbed* is the contradictory of the purely random. This regime produces an output stream of elements that are related to each other, but not in a fully deterministic manner — e.g., in the sequence {A, x, C, D, E, ...} in Figure 3, "x" acts as a disturbance where "B" would have been the expected output. While the purely random is an unrealisable abstraction, the disturbed is the kind or randomness that we encounter in the world. In fact, statistics, with its notion of probability, allows to describe what we can expect at the output of a system with rules that we cannot fully describe. Thus, the probable can be construed as the superposition of randomness to the output of a deterministic system[9].

The last term in the square, the *modulated*, is particularly relevant to the discussions developed in the rest of this work. It results from the negation of the deterministic, and it refers to the random modification *not of the output* of the system, but of the system itself, of its rules of production. For example, the system is modified when, instead of printing alphabetical characters in ascending order, i.e., {A, B, C, ...}, it prints them in reverse order, {Z, Y, X, ...}.

9 "From Continuity...", *art. cit.*, pp. 92-93.

It is important to note that randomness acts as an exteriority, a force located outside of the system itself that disturbs it or modulates it. It might be that this exterior force is also given by deterministic rules, but from the standpoint of the system it appears as random. It is for this reason that a physicist can hold that the universe is driven by deterministic rules only, and yet examine random phenomena in quantum physics. Such phenomena may appear as random because their rules are not, or cannot, be known[10].

Disturbance and modulation in a system may be further analysed in an input-output form. In the former case, the presence of randomness is superposed, "added", so to say, thus interfering with the output of the system. In the latter case, randomness affects the algorithm of the system itself. Hence, the system changes its behaviour and the sequence of outputs it produces will also be different than without the perturbation.

The input to a system determines its output without altering the system's functioning (its algorithm, in the case of an automaton or deterministic system). For example, the inputs to a simple calculator are the numbers and the operations one types in, and the output will vary depending on both. However, a different output does not mean that the functioning of the calculator has changed (i.e., its capacity to carry out mathematical computations). A more sophisticated example related to music would be a music score editing software that allows the user to create a music score which it then translates into sound (as if it were "playing" the music in the score). A simple way of disturbing the output of the system is playing the piano as the music of the software sounds, since the resulting sound will in that case be the combination of both. A modulation of the system would correspond to reprogramming the software so that, in addition to sonifying the written music, it automatically creates a piano accompaniment that is included and played together with the written score. This case would require modifying the algorithm (i.e., the rules of production) of the software.

Disturbance and modulation can be treated as principles that can be extrapolated. A disturbance can be superposed at the input as well — e.g., the user of the music score software accidentally inputs an incorrect note in the score. If modulation is the modification of the rules of a system, those rules can also be modified to the point that a new set of rules is produced that enables the system to carry out other functions. This idea allows of conceiving a complex system composed of subsystems. Each subsystem may require its input, and disturbance and modulation can apply to each subsystem or to the input as the whole. The input can then become of a different sort, and we could also have an input that allows to select which subsystem is activated in the system or automaton. For example, the music software can have the functionality of playing back the score the user inputs, but it can have another functionality (subsystem) that allows it to convert the score into a MIDI or any other sort of audio file. The user

10 See M. Bera et al., "Randomness in quantum mechanics : philosophy, physics and technology", *Reports on Progress in Physics*, 80, 12, 2017.

can select which functionality to use, and in addition provide the parameters required for that functionality to work.

These extended possibilities are important, because they lead us closer to the notion of the actant Subject. In Greimasian and post-Greimasian semiotics, a Subject is not an automaton (a deterministic system) that invariably executes one action program or algorithm. The actions of the Subject depend on the Subject's intention or purpose, i. e., on its Object of desire[11]. This is analogous with the selection of subsystems. An automaton depends on an external input to determine its functionality. In contraposition, a Subject is driven by its intentions of action, but these result from the interaction between Sender (a transcendent entity) and the Receiver. The Sender, then, can be conceptualised as a perturbation to the input of the system, and depending on its influence a certain action program will be pursued by the Subject.

The Helper and Opponent actants (as defined in the initial version of Greimas's grammar[12]) can function as a perturbation of the system (modulation) or as a perturbation of the output (disturbance). In the first case they affect the Subject's immanent actualising modality (knowing-how-to-do), whether in favor or against the Subject's intention of action. In the second case they can introduce unexpected new sequences into the narrative program for the benefit or harm of the Subject's quest — they modify the conditions for the Subject to fulfil its intention of action, its being-able-to-do. For example, if a string of your guitar breaks, this would count as a negative disturbance. It interrupts your playing, but it does not affect the fact that you are capable of playing. Taking guitar lessons, however, will modify your knowing-how-to-do and would hence count as a modulation.

3. Manipulation and feedback

In this section I argue that feedback is implicit in Greimas's schema of the Subject on a quest — an idea addressed already by the author in previous writings[13].

Let us begin by considering Greimas's canonical narrative schema and his actantial model[14]. Both describe the process by which an actant Subject first acquires an intention of action or a desire for an Object of value due to a relation of *manipulation* by an actant Sender. Next, the Subject acquires the *competence* necessary to carry out this action (i.e., to *perform*) in the form of the modalities being-able-to-do and knowing-how-to-do. Once it possesses competence, the Subject performs — i.e., acts so as to get *conjoined* with the Object (or fails to do

11 Cf. A.J. Greimas, *On Meaning*, Minneapolis, University of Minnesota Press, 1987, pp. 84-105.

12 Cf. *Sémantique structurale*, Paris, Larousse, 1966, pp. 178-180.

13 Cf. J.F. Miranda, "Competence, Counterpoint and Harmony : A triad of semiotic concepts for the scholarly study of dance", *Signata*, 11, 2020 ; "Rethinking Knowledge-that and Knowledge-how : Performance, Information and Feedback", *Studia Universitatis Babes-Bolyai-Philosophia*, 65, 3, 2020.

14 A.J. Greimas and J. Courtés, *Sémiotique. Dictionnaire raisonné de la théorie du langage*, Paris, Hachette, 1979, pp. 244-247 (entry "Narratif (Schéma —)").

so, then remaining in a state of *disjunction*). The outcome of the performance is then sanctioned, positively (reward, recognition) or negatively, by the Sender.

Landowski made a significant contribution in postulating that the canonical narrative schema, to which he refers as the *regime of manipulation*, is only one of four possible regimes by which signification may be produced, the other three being programming, accident and adjustment[15]. The *regime of adjustment* is the most complex regime. It even requires a new competence, different from modal competence, namely *esthesic competence*. While modal competence is about being-able-to-do and knowing-how-to-do, esthesic competence is about sensibility (being-able-to-feel and making-others-feel). I propose a reinterpretation of sensibility as perception to put forward the following claim that relates adjustment and manipulation : the actant Sender is implicitly endowed with a faculty to perceive. Otherwise, how could the Sender *know* the outcome of the Subject's performance in order to sanction it ? Depending on the narrative, the Sender might be constructed as perceiving from "the eye of God", i.e., knowing everything that happens without any sort of bias, but this does not contradict the fact that it perceives, for perception is the only way of sensing what goes on in the world. Therefore, I argue that esthesic competence was already covertly at play in the regime of manipulation, since perception is impossible without sensibility. We can only perceive if we are affected by the world. At the same time, sensible perception is also a cognitive process that structures and filters relevant information from the world depending on our intention or ongoing action process[16]. Furthermore, research on cognition has shown that there is a strong coupling between perception and action[17].

The triad intention-perception-action has the feedback loop as its elementary structure. A concise introduction to the feedback loop is provided in the Appendix. Feedback is an essential concept because it accounts for the adaptive response of organisms and artificial systems to achieve their goals[18]. In addition, it intervenes in several features of cognition, including prediction[19] and it is also implicit in Greimas's narrative schema. As already known, the narrative schema was first developed taking Vladimir Propp's model, which was the result of the analysis of a large corpus of fairy tales. Fairy tales, as many narratives, tend to provide a definite end (e.g., "... and they lived happily ever after"). The question is, what happens when the hero is not able to accomplish the prescribed mission

15 *Interacciones arriesgadas*, *op. cit.*, p. 48, p. 103.

16 See for instance E.J. Green, "The perception-cognition border : A case for architectural division", *Philosophical Review*, 129, 3, 2020.

17 Cf. D. Farrow and B. Abernethy, "Do expertise and the degree of perception-action coupling affect natural anticipatory performance ?", *Perception*, 32, 9, 2003.

18 Cf., among others, W. Altmann, *Practical process control for engineers and technicians*, London, Elsevier, 2005.

19 See for instance G. Pezzulo and P. Cisek, "Navigating the affordance landscape : feedback control as a process model of behavior and cognition", *Trends in cognitive sciences*, 20, 6, 2016. D. Wolpert, K. Doya, and M. Kawato, "A unifying computational framework for motor control and social interaction", *Philosophical Transactions of the Royal Society of London*, Series B : Biological Sciences, 358, 1431, 2003.

on the first try ? Perhaps the hero must learn more, train more, device a better strategy. In raising the question of "what happens after sanction ?" we are opening the path to shape the narrative schema as a *feedback loop*[20].

The transition from the canonical narrative schema to the feedback loop can be better explained by means of an example. In a first scenario, consider a beginner piano student. The student plays a waltz she studied and the teacher congratulates her. The young pianist is then conjoined with her Object of desire, which was to play the waltz with fluency and expressiveness, which the teacher confirms. This would correspond to the canonical narrative schema. However, this setting is unlikely to represent the repeated interaction processes between the teacher and the student, since the young student is continuing her lessons. Thus we have a second scenario.

The student has the same *goal* or Object of desire, to play the waltz with fluency and expressiveness. The teacher listens and recognises her effort. "You played very well", the teacher says. But after *comparing* her perception of the performance against the goal, the kind sanction of the teacher prays : "Let us try it once more and this time I would like you to play the accompaniment on the left hand a little lighter, so that the melody in the right hand comes forward". In this scenario we already have feedback, for there is a *performance* by the student, a *perception* of the student's performance by the teacher, and a *comparison* or sanction by the teacher. However, in this case feedback is split in two different actants : the teacher / Sender and the student / Subject. It is the teacher that sanctions the student's playing, but it does not simply lead to conjunction / disjunction, but rather to a *modulation* of her performance. In other words, the teacher's perception expressed as oral feedback will modulate the student's performance next time she plays the piece. This second scenario already corresponds to the feedback loop. Note that the sanction provided by the Sender results from a *comparison* of the *goal* against the *perceived performance*. That is, sanction functions as an input for another attempt at the performance with an adjustment in the competence / performance stages. In this sense, experiences of failure or success count as a modulation of the modalities of competence.

In a third scenario, as the student matures as a pianist, she will eventually be capable of making most of the adjustments to her performance herself : the actant Sender and the actant Subject are both immanent to her now. She can sanction her own performance and realise when she can play with more expressiveness, or if a passage needs more practice so that the sound is more fluent. This third scenario continues to correspond to the feedback loop. Then, in a forth and last scenario we have that the student has become already an accomplished pianist. Whereas she previously had to focus on playing the right notes, or correcting the lightness of her playing, in this scenario the student can focus her perception on the sound of the orchestra when she likes (perception of the world) and shift at will to perceiving her own action (listening to her own

20 Cf. J.F. Miranda, "Competence, Counterpoint and Harmony", *art. cit.*

playing). Now she does not focus as much on pressing the right keys, but rather on the quality of sound, even if most of the time it is as if she did not think about it (hence sanction plays a much less significant role given her experience and command of the piano).

The discussion provided so far has put forward two operations by which the modification of a system is possible : disturbance (a perturbation is superposed to the output of the system) and modulation (a perturbation affects the functioning of the system, its capacity to act, its rules or principles of production). Considering that many action processes do not have a fixed ending (conjunction / disjunction) but rather the Subject has the possibility of repeating the performance, we have claimed that feedback is the elementary actantial device that expresses this adjustment process (a modulation of performance by the degree of failure or success from previous experiences). The outcome from the sanction process is not regarded as a binary (conjunction-disjunction) but rather as an error to be minimized. This error can modulate the performance, but in complex systems it is also capable of modulating the very formation of intentions of action.

The feedback loops that have been presented are of reduced complexity, yet they are effective at modelling learning processes (i.e., processes of acquisition and modulation of competence).

4. Adjustment and feedback

In this section we set out to analyse the regime of adjustment in terms of feedback, contrasting it with the other three regimes of signification, namely programming, accident, and manipulation[21].

While programming is founded on regularity and driven by invariant repetition, accident is characterised by randomness and the unforeseen. Thus, unilateral adaptation of one actant to another does not correspond to adjustment, but to programming. Given that we know how a deterministic system functions, we (the Subject) adapt our actions in order to utilise the program to our benefit. In adjustment, the behaviour of the interactant (human or other) with whom a Subject interacts has its own dynamics and these cannot be reduced to preestablished laws[22]. Adjustment is about meaningful interaction between two or more Subjects, the principles of which emerge from interaction itself. The aesthesic competence mentioned in the previous section is therefore fundamental. Each of the actants engaged *feels* the way of acting and reacting of the other, whether it is a coparticipant or a rival[23].

Adjustment should also be distinguished from manipulation. In manipulation, the Sender persuades the Subject to embark on a quest to realise the Sender's intention. That is to say, there is a vertical relation in the formation of intentions of action. The pair Sender / Subject is hence analogous to the relation

21 Cf. *Interacciones arriesgadas, op. cit.,* pp. 45-59 and 81.

22 *Ibid.,* p. 46.

23 *Ibid.,* pp. 53-59.

transcendence / immanence. In adjustment, the other is treated as a Subject in its own right, and most importantly, intentions of action are *jointly produced*. Instead of seductive procedures, esthesic competence is the key to understand each other and engage on meaningful interaction. The cognitive competence deployed in manipulation is also at play in adjustment, so that both interactants are able to modulate each other's performances and construct together a common intention of action as well as the specific dynamics of their interaction. In manipulation, the Subject strives to bring virtual intentions to reality. In adjustment, there is a dynamic interplay between virtual intentions and their ongoing realisation.

How can adjustment be analysed in terms of feedback ? One may imagine a first scenario, where the intention of action has already been agreed upon. Imagine that two musicians are going to play music together. Both have agreed to play the same tune, John on the piano, Mary at the violin. First of all, we should be aware that John and Mary share a common world. That is, both change the world with their playing, and both can perceive these changes. If John is to ensure that he plays the same melody as Mary, he must be constantly comparing the melody he plays on the piano with the melody Mary plays on the violin. Their shared intention of playing the same melody entails that John should strive to minimise the discrepancy between both perceived melodies (i.e., minimise the error). John's performance will then be modulated by three fundamental perceptions : the perception of his own playing, that of Mary's playing and that of the difference between the two. If any of these three perceptions were completely absent, adjustment would be impossible. Identical considerations apply to Mary. Adjustment in this example is present in the fact that both John and Mary modulate their performances striving to minimise the discrepancies between their melodies, which requires an esthesic competence to sense / perceive each other as well as a cognitive competence in order to modulate their performance appropriately.

From this simple case we can already extrapolate to a scenario where Mary plays the melody of *Twinkle, Twinkle, Little Star* and John accompanies her. In this case, the intention would not be to minimise the discrepancy between their melodies, but rather to minimise the discrepancy between certain key perceptual features — e.g., pulse, meter, tuning of their instruments, the joint harmony between John's piano and Mary's violin. If both are experienced musicians, however, their goal would be to maximise their musical expressiveness (to "develop a chemistry while playing", as it were). This is related to the minimisation of the other variables listed before, but in this case we could add the minimisation of the discrepancies between the volume of their instrument in a given melodic sequence[24]. A similar feedback diagram could be drawn to illustrate the case where John and Mary jointly produce a common intention of action — e.g., if

24 In her research in the relation between rhythm perception and movement, M.R. Haugen points out that the experience of musical rhythm relies in the creation of endogenous reference structures such as pulse and meter. M.R. Haugen, "Investigating Music-Dance Relationships : A Case Study of Norwegian Telespringar", *Journal of Music Theory,* 65, 1, 2021.

they decide that they will improvise based on *Twinkle, Twinkle, Little Star*. We would now have to include one more process for the formation of intentions, which will also be modulated by the three basic perceptions (i.e., perception of one's own actions, of the other's action and of the difference between the two).

This discussion on adjustment and feedback shows that Landowski's regime of adjustment can be analysed in terms of feedback. Just as in the case of manipulation, more complex feedback processes informed by empirical and theoretical research in cognition are possible. For example, a feedback model can be used to account for how we learn to imitate each other's actions, thus providing a link between motor control and social interaction[25]. In general, learning movement skills or performing skilfully requires effective and efficient gathering and processing of sensory information that is relevant to an action (i.e., an adjustment in perception). Adjustment of perception and action can be error-based, but it can also include reinforcement learning (i.e., learning from experiences of conjunction or intentions) as well as observational learning and use-dependent learning.

5. Entrainment, Harmony and Rhythm

Entrainment and Rhythm are closely related, but entrainment has a number of different meanings. In this section I address some of these meanings in relation to Rhythm and rhythmic experience. It will be shown later on that entrainment can be related to feedback and to the regime of adjustment. In this exposition I use Subject and Object as actants to describe the different relations of entrainment.

While entrainment is often associated with periodicity, it is not necessarily so. In chemical engineering, "entrainment is when a fluid picks up and *drags* another fluid or a solid"[26]. This process of dragging that one fluid exerts on another is analogous to dyadic relations such as affect (e.g., a "groovy" rhythm affecting our mood) or causality (e.g., an event causing another event). This form of "dyadic entrainment" should not be neglected, as it forms an integral part of rhythmic experience and sensible experience in general.

On the other hand, entrainment is related to periodicity and coordination or coupling. For example, J.C. Phillips-Silver and his colleagues define entrainment as "spatiotemporal coordination resulting from rhythmic responsiveness to a perceived rhythmic signal"[27]. F. Cummins, for his part, defines it as "the yoking together of two oscillatory systems such that their periods of oscillation become related"[28].

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25 Cf. D.M. Wolpert et al., "Principles of sensorimotor learning", *Nature reviews neuroscience*, 12, 12, 2011.

26 "Entrainment", Collins *Dictionary* (https://www.collinsdictionary.com/es/diccionario/ingles).

27 J.C. Phillips-Silver et al., "The ecology of entrainment : Foundations of coordinated rhythmic movement", *Music perception*, 28, 1, 2010, p. 3.

28 F. Cummins, "Rhythm as an affordance for the entrainment of movement", *Phonetica*, 66, 1-2, 2009, p. 19.

If entrainment in relation to periodicity is to be properly understood, we must refer to the experiment of the Dutch scientist Christiaan Huygens[29]. J. Peña Ramirez provides us with a vivid explanation :

> Two of his recently invented pendulum clocks — which were hanging from a common wooden beam placed at the top of two chairs — were showing an "odd sympathy". Namely, the pendula of the clocks were oscillating in perfect consonance but in opposite directions, i.e. the clocks were synchronized in anti-phase. (...) Although at that time Huygens did not have the proper mathematical tools for explaining his observations (...) he managed to find the mechanism responsible for the sympathy in his clocks : (the small vibrations of) the wooden bar on which the clocks were hanging.[30]

Huygens's finding is remarkable in several respects. First, we have two objects that *adjust* to each other towards a perfect match without being guided by any intention (both are Objects in the Greimasian sense). Second, as the clocks tends towards phase alignment, in every oscillation period the phase in the next iteration or period is slightly adjusted — it depends on its current value and on the difference in phase between both pendulums, a small error that is progressively compensated for. In other words, a *feedback* mechanism guides the phase alignment. Third, the pendulum of the clocks align in phase only because of the wooden bar that *connects* them. Fourth, entrainment entails a reduction of system complexity due to *coupling*[31] — e.g., whereas without entrainment we would have needed an ordered pair (phase of clock 1, phase of clock 2) to describe the current positions of the clock pendulums in real time, after entrainment takes place we only need to know the phase of one of the pendulums at any given time and know the phase relation between the two pendulums (e.g., in-phase or anti-phase) to know the phase of the other pendulum.

In the previous article I relied on Leibniz's definition of Harmony as "diversity compensated by identity [i.e., unity]"[32]. Notwithstanding, it was unclear what sort of unification mechanism could underlie a tendency towards unity. Carlin's interpretation of Leibniz suggests that Harmony "results from simultaneously considering a collection of entities such that they may be distinguished from one another", allowing the inference of "a range of properties" of the collection[33]. I argue that Rhythm is a species of Harmony insofar as it is regarded as a unifying force compensating diversity with entrainment and periodicity as its specific mechanisms. The difference with Leibniz, however, is that rather than focusing on order, the Harmony that Rhythm is a species of can be more fruit-

29 P.S. Spoor and G.W. Swift, "The Huygens entrainment phenomenon and thermoacoustic engines", *The Journal of the Acoustical Society of America*, 108, 2, 2000.

30 J. Peña Ramirez et al., "The sympathy of two pendulum clocks : beyond Huygens' observations", *Scientific reports*, 6, 1, 2016, p. 1.

31 Cf. F. Cummins, *art. cit.*

32 "From Continuity...", *art. cit.*

33 L. Carlin, "On the very concept of harmony in Leibniz", *The Review of Metaphysics*, 2000, p. 125.

fully understood as an *active* unification mechanism that integrates a collection of entities *into a system* that functions as a whole. It is not only that the collection acquires common properties that we may infer, but that it actively strives to preserve them. What is meant by "actively" ? Given that entrainment is based on feedback, the system will be structured in terms of one or more feedback loops with different hierarchies and priorities. The goals of each loop will configure the functioning of the entities that comprise the system so as to preserve the common properties it iteratively acquires. For example, in the case of Huygens's clocks, feedback allows for the minimisation of phase discrepancy between them and prevents phase discrepancy from increasing again.

6. Entrainment in its five dimensions

The practical relevance of entrainment can be further extended if we consider what we humans do when we play music or dance together. The way in which we entrain each other by means of playing a common rhythm are not straightforwardly deterministic as with the two clocks. They correspond to the *regime of adjustment* described in the previous section — a double feedback system composed of two Subjects and a common world. The result of adjustment, as that of entrainment, is to establish one or many commonalities that were not present before. Just as the two clocks aligned the phase of their oscillations, when John and Mary play the piano and the violin their actions do not simply become coordinated respect to a common pulse. There will be endogenous perceptual structures mediated by culture (e.g., meter, tonality, expressiveness of playing) according to which they couple their actions. In spite of coupling their actions based on these common structures or perceptions, this coupling does not *determine* but rather *constrain* John and Mary's behaviour when playing together. For example, John can device many possible piano accompaniments for Mary's rendition of *Twinkle, Twinkle, Little Star* just as Mary could adjust features of her style of playing to John's accompaniment (e.g., sound quality, timbre, volume intensities or improvising a different melody). In technical terms, we could say that John's playing *affords* Mary certain options in her own playing and viceversa[34]. If Miguel enters the room and wishes to dance, there are a myriad of ways in which he can move while following the rhythm of the song.

Entrainment acquires an additional degree of complexity if we consider the semiotic distinction between plane of expression and plane of content. This difference can be understood as the difference between the "exterior" and "interior" worlds[35]. The boundary between both worlds, however, is not given in advance, nor is it the result of a "consciousness". As J. Fontanille puts it, it is rather the one that "a living being puts into place each time that it accords signification to an

34 For an in-depth discussion of affordances, cf. A. Chemero, "An outline of a theory of affordances", *How Shall Affordances be Refined ? Four Perspectives*, London, Routledge, 2018, pp. 181-195.

35 Cf. J. Fontanille, *The semiotics of discourse*, Bern, Peter Lang, 2006, p. 11.

event, a situation, or an object"[36]. For example, in two different settings, a fruit's color (plane of expression) can be put into relation with the sweetness of its flavour or with how long it will take to rotten (two different planes of content). The boundary between expression and content is not predefined, but rather set by a taking of position of the sensible body[37]. The distinction between the two planes can now be related to the Subject / Object distinction during entrainment. Given that Objects do not have a plane of content, their entrainment always takes place in the plane of expression. Of course, it can be that a Subject (such as Huygens) adds a third relation in the plane of expression or the plane of content — e.g., as the two pendulums move in-phase, Huygens imagines a third pendulum moving twice as fast as the other two. In the case of dancing together, there might be entrainment taking place in both planes. On the one hand a coupling in the timing of your bodily movements takes place (with the music as a mediator). On the other hand, cognitive states of perception and action control that correspond to the plane of content can be entrained (e.g., feedback adjustment based on touch, visual perception, kinesthesis and motor system control).

Consider a peculiar case. You are in the middle of nature and you can hear the periodic sound of a water drop falling on to a tree leave. You do not move, but sit down and listen. Maybe you even manage to imagine a complementary rhythm that matches the pulse of the water drops. This simple scenario illustrates entrainment taking place between the plane of expression (the sound of the water drops) and the plane of content (your own simulacra of the sound of the water drops or your imagined complementary rhythm).

From this discussion, we can identify the following variables related to entrainment : 1) the *actantial status* of the two entrained elements : Subject or Object ; 2) the *directionality* : unilateral (X is entrained to Y) or bilateral (X and Y are mutually entrained) ; 3) the *flexibility of their relation* : deterministic (e.g., the two clocks) or constrained (e.g., John and Mary playing music together) ; 4) *mediatedness* : immediate (entrainment as dragging or affect) or mediated (the two clocks) ; 5) *planes of entrainment* : plane of expression and/or plane of content.

The binary combinations of these five variables, considering that entrainment requires at least two entrained elements, gives rise to 64 different possibilities. Fortunately, these variables are not entirely independent but correlated. Table 1 lists what we regard as the most representative cases.

36 *Ibid*.

37 *Ibid*.

	Relations	*Mediation*	*Flexibility*	*Plane*
"Drag"	O1 entrains O2	immediate	deterministic	E-E
	S entrains O	immediate	deterministic	E-E
	O entrains S	immediate	deterministic	E-E or E-C
Manipulation	O entrains S	mediated	constrained	E-E or E-C
	S1 entrains S2	mediated	constrained	E-E or E-C
Adjustment	O1 and O2 entrain each other	mediated	deterministic	E-E
	S and O entrain each other	mediated	constrained	E-E or C-E
	S1 and S2 entrain each other	mediated	constrained	E-E or E-C

Table 1. Representative relations of entrainment considering five variables : actantial status, directionality, mediation, flexibility and plane. It is possible that in a given semiotic system several of these relations of entrainment happen simultaneously.

Conclusion

This work was inspired by Victoria Santa Cruz's insight that Rhythm is a concept that extends beyond music and dance, one that denotes a *continuous becoming*. Moreover, Rhythm in this view is an active principle that integrates and organises unities to form more complex ones. A number of questions motivated this investigation : if Rhythm is a continuous becoming, what is continuity ? How are unities delimited and reorganised ? What mechanism of integration takes place in Rhythm ? Could these questions be answered in a semiotic definition of Rhythm ?

My answer is affirmative and structured into three interrelated efforts. The first effort, developed in the first article, was the analysis of the opposition of continuity *vs* discontinuity. This analysis led to a better understanding of the nature of continuity by unfolding it as a complex of three oppositions : self-identity *vs* difference, unity *vs* diversity and determinism *vs* randomness. On the other hand, it put forward the notions of difference, coexistence, continuity, cohesion, all of which were necessary to understand and describe Harmony as a semiotic concept. In short, the analysis of continuity led to difference and thereby to Harmony. Moreover, the first article concluded suggesting that Rhythm is Harmony where entrainment acts as a unifying mechanism. Therefore, whereas some claim that a condition for Rhythm is segmentation into units[38], we would rather say that the elementary condition for Rhythm is difference. In Greimasian terms, this amounts to identifying an opposition that marks two different poles from which other oppositions may stem. This agrees with the fact that we associate musical rhythm with high and low volume intensities in the form of accents, or with sound and silence, and, in the case of dance, with tension and relaxation. Moreover, positioning difference at the core of Rhythm agrees with the Greimasian account of how signification is produced in general.

38 Cf. L. Hébert, "A Little Semiotics of Rhythm. Elements of Rhythmology", *Signo*, 12, 2011.

Given the definition of Rhythm the first article suggested, the second effort set out to understand entrainment in semiotic terms. I have explained how entrainment can be analysed in terms of feedback and that, when involving mediation as in Huygens's pendulum clocks, it relies on periodicity as a mechanism that operates both in the plane of expression (i.e., in the physical world) and in the plane of content (i.e., the mental world of an actant). While in the case of inanimate objects entrainment may be deterministic, it is certainly not so in more complex systems such as human beings and other organisms. Furthermore, recurring to feedback, this work has shown that manipulation and adjustment, two regimes of signification put forward by Landowski, can be construed in terms of entrainment.

The third effort revisited the relation between Harmony and Rhythm. For Leibniz, Harmony is diversity compensated by identity. In addition, Leibniz postulates what I refer to as a "principle of optimality", i.e., that which is maximally diverse and maximally unified is maximally harmonious. An important drift of Rhythm from Leibniz's Harmony lies in the approach towards unity — whereas the former focuses on *compensation* as an active operation or force, the latter focuses on *identity* as an ordering principle of a collection of entities. More specifically, I define Rhythm as *diversity compensated by two mechanisms or forces : periodicity and entrainment*. Periodicity acts as a unifying force in virtue of repetitions that hold a common property to each other, their equidistance or period. Periodicity is the basis for Rhythm, but it does not constrain it to be a monotonous succession. First, because both the system and the periodic sequence it generates can be affected by randomness or singularities. This allows for higher degrees of cohesion or unity. Second, because periodicity enables the superposition or combination of different periodic structures with related periods. In addition, considering entrainment (both as "dragging" and as an iterative mediated process between actants) we have that Rhythm tends to entrain other actants. On these two grounds we affirm not only that Rhythm is not constrained to being a monotonous succession, but that Leibniz's principle of optimality applies — i.e., that which is maximally diverse and maximally unified is maximally Rhythmical.

Summarising, when we speak of Rhythm we are thinking of a compensation of difference were identity is an active force rather than a static noun. Rhythm is ongoing, something taking place *in act* rather than *in potency*. Rhythm happens in a here and a now. Given that periodicity is a necessary condition for there to be Rhythm, the definition I provide can accommodate understanding Rhythm "as measure". However, it rather focuses on the consequence of the measured ratios, on the active tendency towards unification that results from periodic, feedback and entrainment relations.

The approach to Rhythm this work argues for will hopefully suit different research interests, both within and outside semiotics. The fact that it places feedback and entrainment at the core of signification will hopefully motivate

its application in the study of a number of interaction scenarios occurring in biology, anthropology and sociology, philosophy and artificial intelligence. The emphasis on periodicity can also allow its application to disciplines were Rhythm is not primarily construed as temporal, for example in painting and architecture.

After the exploratory nature of this study, dragging us in loops from oppositions towards definitions and back again to revisit concepts, we can almost hear Victoria Santa Cruz whispering : "Everything is continuously on the making. In this becoming, there is Rhythm".

Appendix : Introducing the feedback loop

Feedback loops are fundamental both to natural and artificial systems because they provide the system with the capacity to adapt its response to reach a specific goal. Feedback loops are extensively deployed in engineering and computer science, and today they are regarded as a fundamental feature of most cognitive systems.

The formal structure of the feedback loop is best understood graphically. Figure 4 shows a general feedback loop. The *actuator*, *sensor* and *comparison* work together to achieve the *goal* of the system. Actuators exert a relevant change in the world, sensors sense the value of relevant variables of the world and the comparison allows the system to estimate how close or far it is from achieving the goal. What is relevant depends on the goal. For example, consider an electric oven as a system. The goal is to reach and maintain a stable temperature of 180°C. In this case, the relevant magnitude is temperature. Thus, the actuator is the thermoelectric resistance that produces heat as electric current flows through it. The resistance increases the temperature inside the oven and the sensor inside the oven will provide an estimate of how close or far the temperature is from reaching 180°C. The actuator can be turned off if the oven goes beyond the goal temperature, or turned on again if the temperature drops bellow the goal.

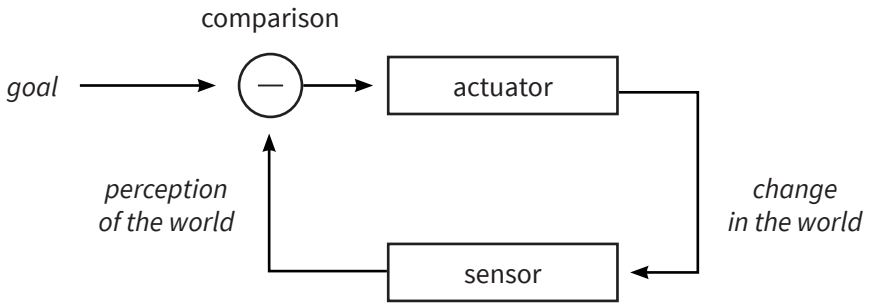

Figure 4. Basic components of the feedback loop : goal, actuator, sensor, comparison. The correspondence with Greimas's and Landowski's semiotics is straightforward : actuating / performing, sensing / sensing, comparing / sanctioning, goal / desiring an Object of value. Actuating / performing adjusts based on the error or feedback resulting from comparison / sanction.

Feedback loops can be nested with each other to form more complex systems. Many organisms and artificial systems (such as Google Adds) are endowed with prediction. It can be shown that prediction is necessarily implemented with several feedback loops. Feedback allows to understand the variations in time of the behavior of a system (or actant, in semiotic terms) and to understand how its goals affect the system's responses or actions. This complex task is pursued by the discipline known as control engineering[39]. In the case of Greimasian semiotics, goals can represent intentions of action (virtual states) and the combination actuator /sensor combine performance and knowledge to attempt conjunction with the goal or Object of value. Sections 3, 4 and 5 in this work provide several of examples of feedback applied to semiotics. For these examples to make sense, however, the basic structure of the loop (actuator, sensor, comparison and goal) must be clearly understood.

Acknowledgements

The author would like to acknowledge Dr. Mari Romarheim Haugen for sharing her insights on the experience of musical rhythm. This work is also indebted to Prof. Cummins for his compelling definition of rhythm in terms of entrainment and his disposition to reply to written correspondence and to Eric Landowski for his clever suggestions to make this article more ameneable to semioticians.

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Résumé : Ce texte est la 2e partie de “From Continuity to Rhythm (I)” (*Acta Semiotica*, II, 3, 2022), article dont l’objet était de définir le rythme comme concept sémiotique. Les bases de cette définition sont le concept de rythme chez V. Santa Cruz, vu comme principe d’intégration actif et continu, la notion de continuité chez E. Landowski, le concept d’Harmonie chez Leibniz, le concept physique d’*entrainment* et la définition du feedback en sciences de l’ingéniérie, pris comme cadre de compréhension de la manipulation, de l’ajustement et de l’*entrainment*. Les points essentiels sont 1) l’analyse des régimes d’ajustement et de manipulation en termes de feedback, 2) l’établissement d’une relation entre manipulation et ajustement montrant que la première se ramène à une simplification du second, 3) une définition de l’*entrainment* faisant apparaître manipulation et ajustement comme des modes d’*entrainment* spécifiques, 4) une définition sémiotique du Rythme comme processus dynamique d’unification, à partir de la notion d’Harmonie chez Leibniz, 5) le réexamen de la notion d’Harmonie chez Leibniz en vue d’une compréhension active du Rythme non seulement comme produisant un ordre et des propriétés communes mais aussi comme tendant activement, en vertu du feedback, à les maintenir.

Mots clefs : ajustement, entraînement, feedback, harmonie, manipulation, rythme.

Resumo : Esse trabalho é a segunda parte do artigo “From Continuity to Rhythm” (*Acta Semiotica*, II, 3, 2022), no qual me propus definir o ritmo como conceito semiótico. As bases dessa definição são o conceito de ritmo de V. Santa Cruz, como princípio de integração ativo e contínuo, a noção de continuidade de E. Landowski, o conceito de harmonia de Leibniz, o conceito físico de *entrainment* e a definição do *feedback* em ciências da engenharia como marco para comprender a manipulação, o ajustamento e o *entrainment*. Os pontos essenciais desse trabalho são 1) a análise dos regimes de ajustamento e manipulação em termos de *feedback*, 2) o estabelecimento de uma relação entre manipulação e ajustamento, monstrando que o primeiro é uma simplificação do segundo, 3) a proposição de uma definição de *entrainment* pondo em ação cinco dimensões e fa-

zendo aparecer manipulação e ajustamento como modos de *entrainment* específicos, 4) a proposição de definição semiótica do Ritmo como proceso dinâmico de unificação a partir da noção de Harmonia de Leibniz, 5) o reexame da noção de Harmonía de Leibniz visando uma compreensão ativa do Ritmo não somente como produtor de uma ordem e propriedades comuns, mas também como tendência ativa de sua manutenção em virtude do *feedback*.

Abstract : This work is the second part of the article "From Continuity to Rhythm" (*Acta Semiotica*, II, 3, 2022), where I set out to define rhythm as a semiotic concept. The cornerstones for such a definition are Victoria Santa Cruz's concept of Rhythm as an active and continuous principle of integration, Landowski's understanding of continuity, Leibniz's notion of Harmony, the physical concept of entrainment, and the formal definition of feedback from engineering as a framework to understand manipulation, adjustment and entrainment. The main contributions are : 1) analysing the regimes of adjustment and manipulation in terms of feedback, 2) establishing a link between manipulation and adjustment, showing that the former is a simplification of the latter, 3) providing a semiotic definition of entrainment that considers five different dimensions, expressing manipulation and adjustment as specific modes of entrainment, 4) providing a semiotic definition of Rhythm as a dynamic unification process departing from Leibniz's notion of Harmony, 5) questioning Leibniz's Harmony in favor of an active view of Rhythm that not only produces order or common properties, but that actively strives to maintain them in virtue of feedback.

Resumen : Este trabajo es la segunda parte del artículo "From Continuity to Rhythm" (*Acta Semiotica*, II, 3, 2022), donde me propuse definir el ritmo como un concepto semiótico. Las piedras angulares para tal definición son el concepto de Ritmo de Victoria Santa Cruz como un principio activo y continuo de integración, la continuidad formulada por Landowski, el concepto de Armonía de Leibniz, el concepto físico de *entrainment* o arrastre, y la definición formal de retroalimentación tomada de la ingeniería como un marco para comprender la manipulación, el ajuste y el arrastre. Las contribuciones de este trabajo son : 1) analizar los regímenes de ajuste y manipulación en términos de retroalimentación, 2) establecer un vínculo entre los regímenes de manipulación y ajuste, demostrando que el primero es una simplificación del segundo, 3) proponer una definición semiótica del arrastre que considera cinco dimensiones distintas, según la cual la manipulación y el ajuste son modos de arrastre, 4) proponer una definición semiótica del Ritmo como un principio de unificación activo partiendo de la Armonía de Leibniz, 5) cuestionar la Armonía de Leibniz en favor de una comprensión del Ritmo como integración activa, que no sólo produce orden o propiedades comunes, sino que, debido a la retroalimentación, activamente tiende a mantenerlas.

Auteurs cités : Jacques Fontanille, Algirdas J. Greimas, Eric Landowski, Victoria Santa Cruz.

Plan :

Recebido em 30/09/2022.
Aceito em 30/10/2022.