PROCESS, CONSCIOUSNESS, AND INTEGRATED INFORMATION

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Abstract: Process aspects are prevalent in many domains of reality, and consciousness is no exception. Nevertheless, while the processual approach implicitly underlies the theories of consciousness, an explicit statement of the question is scarcely found in the literature. This paper tries to bridge this gap. Here, I argue that conscious experience fulfils all the requirements for a processual analysis: it is complex, functionally/causally determined, and has a temporal basis.

Then, I revisit an old concept, self-transformative processes, which refers to processes that change themselves. These processes are very common. A stretched bow is the classical Heraclitean example. However, it is easy to misunderstand what self-transformativeness is. To provide a well-formed description, I

characterize self-transformative processes in terms of composition (using a non-classic mereology) and in terms of functionality (by developing the concept of self-modulating variables).

Finally, I apply self-transformative processes to explain consciousness. Traces of self-transformativeness can be found in many theories of consciousness, particularly when they are stressed about their internal mechanisms. Here, I focus on Integrated Information Theory as a paradigmatic example of a mathematically well-described theory, and I demonstrate that quantitative self-transformativeness is a requirement at the very core of the integration of the information.

1. Intro

This paper deals with process and conscious experience. These two topics are often discussed independently; however, it is uncommon to find an interconnected exploration of both. To put it bluntly, these are my aims here: first, to advocate the idea that conscious experience is the kind of entity that demands a process-based analysis; second, to defend that there is a special kind of processes, namely, self-transformative processes, which are highly valuable in describing reality but mainly neglected and, quite often, not properly defined; and third, to argue that the self-transformative processes are a requirement for some theories of consciousness and, particularly for the Integrated Information Theory.

Here, I address a longstanding gap. Admittedly, neuroscientific approaches have considered the temporal properties of conscious experience (Bachmann 2000, Koch 2004, Dehaene 2014). Nevertheless, the concept of process has often been neglected in contemporary philosophical approaches about conscious experience, albeit with some exceptions (cfr. O'Shaugnessy 2000).

There is more than one reason to explain this gap. To begin with, most of the concepts used to address conscious experience have not been interpreted as possessing a truly relevant processive character. This is mostly the case of *representation*, *intentionality*, *endurance*, *subjective character,* or *qualitative character*. Secondly, available processual tools have often been regarded as too variegated and tricky, far from being user-friendly, as clearly illustrated by Whitehead's process philosophy. However, process philosophy has undergone significant changes since Whitehead, and new conceptual tools have been developed. For instance, the notion of *transformative processes* applies to nonproductive, complex, and functionally or causally determined processes (Rescher 1996, 2000). Additionally, the concept of *interference* describes how the composition of transformative processes that affect one another can be (Seibt 2009).

The section 2 attempts to show that the processual analysis based on these new tools is highly advisable for conscious experience. In section 3, I will introduce a variant of transformative process, namely, *self-transformative processes*. In a nutshell, a process is self-transformative if it accomplishes two main conditions: (1) it has a special closeness on its interference structure and (2) the variables that describe the process are related in closed loops where the change in time of those variables is determined by the value of them. Here "closeness" does not mean isolation. I am not referring to closed systems. The world is just not like that. Instead, I am referring to a special composition in the open structure of the systems. My aim in this paper is to describe this composition, that is, to establish what a self-transformative process may be.

The self-transformative aspect of processes is not a red herring. On the contrary, it is very common in reality. A stretched bow, the movement of a spring and a mass suspended from it or the SIR model that depicts the spreading of COVID-19 are just three examples of self-transformative systems tending towards stability. Given the prevalence of this aspect in the natural world, it would be odd not to find it among the processes that underpin conscious experience. As a matter of fact, many neuroscientifically rooted theories include the notion of recurrent connections in neural activity as a natural pattern for the conscious experience. Interestingly, this recurrent aspect has no counterpart on the phenomenological level. In section 4, I will address this question by focusing on a particular theory of consciousness, namely, the Integrated Information Theory (Oizumi, Albantakis & Tononi 2014).

2. Process and consciousness

According to Rescher, a process is "an organized family of occurrences that are systematically linked to one another either causally or functionally" (Rescher 1996, p. 38). He also asserts that "this complex of occurrences has a certain temporal coherence and integrity, and processes accordingly have an ineliminable temporal dimension" (Rescher 2000, p. 24). In this deliberately broad definition there are three key ideas:

(1) Processes are always complex, namely, they are composed of other processes.
(2) Processes are causally or functionally determined. So, spatio-temporal coordinates are not sufficient

to determine processes. Processes are defined by their function or causal powers.

(3) The temporal dimension is essential for processes. A process is something that happens through time.

Everything that has these three characters deserves a processual analysis. A windstorm, a thought, or the photosynthesis, for example, are complex occurrences that occur through time and cannot be fully determined by their spatio-temporal location. So, they can be interpreted as processes. Conversely, if something lacks one of these characters, then it may not be the kind of thing a processual analysis can deal with. For example, a photograph or a frozen image, taken as the representation of an instant, though complex, lacks temporal dimension and can hardly be interpreted as processes.

Conscious experience, on the other hand, is hard to define but we can refer to it ostensibly following Nagel (1974): there is something that is *like to be* in this conscious state *for the subject*. In other words, there is something I am in when I see a red apple, when I feel backache, savour a coffee, or simply feel alive, and I am not in when I come unconscious or sleep without dreaming[1]. Thus, conscious experience exists and has a phenomenal dimension. Is this —is conscious experience— the kind of thing that deserves a processual analysis? So I will argue, attending to the three main ideas above mentioned.

[1] Though Thompson (2015) and Windt (2015) claim that there may be phenomenal character when sleeping without dreaming.

2.1. Is conscious experience complex?

If conscious experience has composition, it may be amenable to a processual analysis. Consciousness is something that happens in the brain, and the brain (and, by extension, the central nervous system) is a complex system. Nevertheless, this does not guarantee that conscious experience is *phenomenally* complex. In fact, the non-experiential part view (non-EPV) is the view that maintains that there is nothing in conscious experience that can be taken as an experiential part because, despite its diversity, conscious experience is completely homogeneous (Tye 2003, especially p. 28).

The question about composition on conscious experience also adds another difficulty, namely, the problem of phenomenal unity, that is, the problem of explaining why conscious experience appears to us as unified despite its diversity.[2] If there are experiential parts, then the problem of phenomenal unity must be tackled. If there are no experiential parts, then the problem is dispensable. Despite that, the non-experiential parts view is by no means prevalent (see, for example, Bayne and Chalmers 2003). Here, I will provide three main reasons supporting the idea that most experiences are complex.

First, it is widely accepted that conscious experience has, at least, two main characters: qualitative character and subjective character (Crane 2000, Zahavi 2005, Kriegel 2009, Sebastián 2012). Qualitative character is what makes a specific conscious experience different from another. For example, there is something that is like to see a red colour

[2] See Searle 1992, Revonsuo 1999, Bayne & Chalmers 2003, Rashbrook 2013.

that differs from what is like to see a blue colour (or listening to a tune). This is the qualitative character. On the other hand, subjective character is the *for-me* part of the conscious experience, that is, the fact that for me (for the subject) there is something that is like to be in the conscious experience. This double character implies, at least, two parts on conscious experience.[3]

Furthermore, conscious experience, when taken as about something real, is an experience of this thing *as it is*.[4] This means that when I see a car I experience it *as* a car, and when I see a cat, I experience it *as* a cat. If the object of my conscious experience is composed, it is common-sense to defend that I see it *as* with a composition. So, the qualitative character of intentional conscious experience needs to have a certain composition. Nevertheless, even when intentionality about real content is not granted, even if conscious experience is, for example, illusionary or hallucinatory, the way we experience it is as something composed. This is because every conscious experience has a *particular* side, that is, it is experienced as this particular experience, here and now. So, it always has a specific content part and a particular content part, underscoring its complex nature.

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[3] Notwithstanding that the subjective character and the qualitative character may be also composed. See Guillot (2017) and Farrell & McClelland (2017).

[4] Searle (1983, 1992) is a conspicuous advocate of this idea. It is also common among some representationalists. In contrast, Seth (2014, 2021) confronts this idea and employs the expression "controlled hallucination" to refer to perception. However, the prediction processing that Seth proposes to explain perceptual conscious experience is by no means non-complex. (See Seth 2014).

Finally, consciousness is an experience of a stream of consciousness, that is as something diverse but with a unity in time (James 1890, Husserl 1913). The usual way to depict this stream of consciousness is as different states or phases that overlap on fringe parts (Mangan 1993). This also means that we need some kind of experiential parts to explain the stream of consciousness.

To summarize, the non-experiential parts view is at odds with classical phenomenology about conscious experience, and it does not align with current positions about consciousness. So, it is a common-sense stance to accept that some experiences, arguably most of them, do have parts.

2.2. Can conscious experience be functionally determined?

Each time I consciously observe the rain from my window there is a bunch of things I can do. I can tweet that "it is raining here, in Pamplona (Navarre)", I can recall where I left my umbrella, or I can hurry to pick up the laundry. No question that cognitive states admit a functional determination, either for reporting, reasoning, or acting. However, what about conscious experiences? Do they admit a functional determination? There are mainly two ways to approach this question: via epiphenomenalism and via the access/phenomenal consciousness distinction.

Starting with the first one, it is easy to mistake functionalism and function on conscious experience.[5] In

[5] For example, two epiphenomenal stands such as Jackendoff (1994) and Chalmers (1996) are functionalist but leave little room for function on conscious experience. Both think that phenomenal

order to clarify this, I will define the principle of functionality (about consciousness) as the assumption that conscious experiences (or their experiential parts) (a) have a function and (b) this function is relevant for cognitive processes. Denying (b) is referred to as weak epiphenomenalism. Denying (a) and (b) is referred to as strong epiphenomenalism.

Strong phenomenalism is taken to be a *contradictio in terminis* (cfr. Searle in Searle, Dennett et al. 1997). It's not possible to claim that conscious experience does exist and that it has no function at all, because otherwise we could not say anything about it. So, the big question about the function of conscious experience is whether weak epiphenomenalism is palatable or not.

This question is also a bit tricky. When we speak about the function of conscious experience it seems that we are only engaged with positive functions. Nevertheless, Baars (1998), maintains that consciousness has both positive and negative aspects. Consciousness slows cognitive processes and makes them less efficient, thus prone to errors. In contrast, conscious processes exhibit "a great range of different contents on time", they show a high capacity to relate those contents and they are very sensitive to context (Baars 1998, p. 75). This trade-off between positives and negative aspects explains the existence of macrodynamics in consciousness, that is, long-run complex processes where conscious and non-conscious processes alternate, akin to a pupil that is learning hand postures to play the piano. This

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level is determined functionally at some level (at a computational or neural level), but they don't think that phenomenal level has any relevant function.

suggests that the question about the relevant function of conscious experience is not-well formed.

Strong epiphenomenalism does not work due to self-coherence reasons and the question about weak epiphenomenalism seems to be misguided. Perhaps a better way to formulate this question is by introducing the distinction between access-consciousness (cognitive access to a content for reporting, reasoning, or acting) and phenomenal consciousness (experience, or what is like to be in that state) (Block 1995).

This distinction may be a methodological one. However, Lamme (2010) and Block (2011) go further by maintaining that phenomenal consciousness may exist without access-consciousness. They refer to empirical evidence such as Sperling (1960) and Vanderbroucke et al. (2010). The intuition they promote is that, although our capacity for visual attention is limited, when confronted with complex visual stimuli, people tend to report that they saw more than they can describe.

Sperling (1960) presented brief visual stimuli based on lettered matrix cards to subjects and asked them to report letters. Next, he repeated the task by retro-cuing the row to report with a beep just after the extinction of the visual stimulus. Subjects had better performance on the second task. This has been interpreted as the subjects having seen more than they were able to report. Vandenbroucke et al. (2014) extended those experiments on different visual stimuli maintaining the retro-cued scenario.

Lamme (2010) and Block (2011) argue that there is a fragile visual short-term memory, associated with phenomenal consciousness but not accessible. For Lamme and Block, all this empirical evidence shows that the intuition that we see more than we can report is not an illusion, but a reflection of the fact that phenomenal consciousness is richer than access-consciousness and, hence, that there are phenomenal parts of conscious states that remain inaccessible.[6]

Notwithstanding the long discussion, I would like to highlight two objections to the idea that there is a phenomenal consciousness *without any kind* of access, i.e., completely functionally undetermined. Firstly, the scenarios presented by Lamme and Block are lab-based (brief presentation, masking, retro-cue), and they do not exhaust the functional diversity of visual conscious experience. Secondly, those experiments also possess a functional structure at their very essence. They refute that all conscious states are directly accessible (for reporting, reasoning, or acting), but they need to accept some kind of indirect accessibility, which is elicited by retro-cueing. Hence, those states are, in some way, also functionally determined.

2.3. Is temporal dimension relevant for conscious experience?

The temporal properties of conscious experience are something rather new in the landscape of consciousness studies.[7] We know from backmasking evidence with metacontrast that visual conscious experience needs time for ignition, somewhere around a hundred milliseconds (cfr.

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[6] Cohen and Dennett (2011) dispute this interpretation.

[7] They emerge in the literature (at least, in a systematic and scientifically-grounded way) during the 20th century, especially aligned with the progress in neuroscience. See Libet (1963) and Libet et al. (1979).

Bachmann 2000).[8] We also know that this ignition time may be faster (or slower) under certain conditions (i.e., the flash lag effect, Watanable et al. 2010, also Bachmann 2000). Perhaps because of its novelty, temporal properties are sometimes taken to be irrelevant, and scarcely mentioned in some of the debates about consciousness (especially in modal argumentation, see Chalmers 1996). Is this lack of attention justified? It may seem clear that we need to consider temporal properties to explain the conscious experience of listening to a Beethoven's symphony (given that music unfolds over time). However, can we really neglect those temporal properties when dealing with the "what is like to be in" side of seeing a red tomato, experiencing pleasure, or feeling pain? I will provide several reasons to support the relevance of temporal properties, (and, consequently, of processual analysis).

The first and main reason is that we need to explain conscious experience in this world, with these special idiosyncratic characters, which include all kinds of properties, namely, phenomenal properties, but also functional, compositional, and temporal properties as mentioned above. We simply cannot (should not) take some properties and discard the others. They all come in the same package.

For example, the stream of consciousness (or diachronic unity) is a property of conscious experience (Brentano 1874, James 1890) and it really makes no sense to preclude the

[8] Metacontrast based masking is one of the best-known experimental paradigms to study the temporal properties of visual conscious experience. See Alpern (1953), Dehaene et al. 2001, Del Cul et al. 2007, Bachmann & Francis 2014.

temporal properties from its *explanandum*. As James puts it, "into the awareness of the thunder itself the awareness of the previous silence creeps and continues; for what we hear when the thunder crashes is not thunder pure, but thunder-breaking-upon-silence-and-contrasting-with-it" (James 1890, pp. 240-241). We do need a group of properties related with ignition and fading of successive experiences to account for this unity that happens in time.

By the same token, we cannot privilege some paradigmatic types of conscious experience which seem "atemporal" over other non-paradigmatic conscious experiences in time. The problem is that the literature has been typically focused only on those paradigmatic cases of conscious experience, like "seeing a red tomato", "feeling a pain" or "feeling pleasure" (Locke 1689; Wittgenstein 1953; Block & Fodor 1972; Nagel 1974; Jackson 1982). Still, there is a multitude of non-paradigmatic conscious experiences whose explanation ask for consideration of all successive experiences, how they emerge, how they fade, and how they contrast. Non paradigmatic cases of conscious experience include fringe experiences such as "feeling a growing or a decreasing pain", "having the feeling that something is going wrong", "having something in the tip of the tongue", "feeling passing time".[9] These are ongoing experiences closely related with temporality.

All these considerations become even more apparent when discussing temporal consciousness. Temporal consciousness is the conscious experience of time, which refers, at least, to four possible dimensions: the experience of the present (the now, sometimes called "the specious

[9] For a characterization of fringe experiences, see Mangan (1993).

present")[10], the experience of succession, the experience of continuity (on that succession) and the experience of duration (Dainton 2000, 2018). Here, temporal properties of conscious experience are fundamental, and they make the difference between the explanatory models, namely the extensional approach, the retentional approach or combination of both (Dainton 2018, Montemayor 2017). Note also that this conscious experience about time is far from being anecdotal or merely another kind of intentional experience. On the contrary, it may be closely related with the phenomenal now and what is sometimes called the pure consciousness events (Windt 2015 and Forman 1990, respectively).

So far, I have given some reasons to believe that conscious experience has phenomenal, compositional, functional, and temporal properties and, hence, that processual analysis is appropriate and highly advisable for it. Now I will introduce a kind of process that may help for this task, namely, self-transformative processes.

3. Self-transformative processes

There is a sort of process before our very eyes which, despite being widespread, has not received enough attention yet.[11] It can be found in artifacts such as a stretched bow, a

[10] James (1890).

[11] At least, not in some areas of philosophy of mind. However, self-transformativeness boasts a long tradition tracing back to Heraclitus and the *palíntonos harmoniē*. It has also been used in cybernetics (Wiener 1948), in embodied cognition (see the perception-action loop, cfr. Shapiro 2011) or in neurology (see

spring and a mass, or in artificial control systems based on feedback. Additionally, it can be found operating in nature, especially in self-controlled and self-enhanced systems such as ecosystems, and also in the brain.

Self-transformative processes are in the air. Still, they are barely mentioned in literature about consciousness. This section is, first and foremost, a revindication of self-transformative processes by characterizing them properly. The starting point will be transformative processes. Transformative processes are processes that "merely transform state of affairs in general, paving the way for further processes without issuing in particular things or states thereof" (Rescher 1996, p. 42). Transformative processes contrast with productive processes. Productive processes generate an end result, namely, a thing (that is, something spatio-temporally determinable), while transformative processes do not (at least, not necessarily). The manufacture of a car is a typical example of a productive process that ends in a particular thing. In contrast, windstorms and earthquakes are examples of pure transformative processes, in the sense that they don't admit a precise spatio-temporal definition and they do not generate a particular end result. Most processes in the world lie somewhere in between. Nevertheless, Rescher highlights that "process philosophy is characterized by its insistence on the fundamentality of transformative processes, with their potential detachment from substantial things" (Rescher 2000, p. 28). So, for process philosophy, transformative processes have explanatory priority over productive processes.

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reentrant neural networks in Edelman 1989 and recurrent processing in Lamme 2010 or Dehaene 2014).

Self-transformative processes are literally processes that transform themselves or their own states of affairs in general. To begin with, two caveats are imperative here. First, self-transformativeness does entail a sort of closure, but not isolation, in the sense we speak of closed and isolated systems in thermodynamics. Just like a stretched bow can be controlled by the archer, self-transformative processes are sensitive to external conditions, alterations, and control mechanisms. Second, self-transformativeness is not a trivial claim. The world *as a whole* is, *lato sensu*, a self-transformative process. It is full of self-controlled processes (e.g., tides, the water cycle, meteorological phenomena). However, self-transformativeness, *stricto sensu*, refers to specific and well-defined ways of transformation, namely, transformations where the change in time of the variables that describe the system depends on the value of those variables in a closed loop. I will give a mathematical example to illustrate this nuance. The expression f(x)=f(x) is a trivial statement. On the contrary, the expression x'=f(x), where x' represents the change in time of x, describes non-trivially what will happen with x in time.

We know what self-transformativeness is not. It is not isolation, and it is not a trivial statement about the world *as a whole*. What is, then, a self-transformative process? To adequately characterize self-transformative processes, it's crucial to establish two conditions all member of this sort of processes must match:

(1) Self-transformative processes have a composition based on closed interference loops.
(2) The variables that describe how a self-transformative process evolves in time are coupled, so they change in time according to their values in a closed-looped way (I will call this *self-modulation*).

The first condition is compositional, while the second one is functional.[12] The next sections are devoted to explaining precisely what constitutes the basis of these two conditions.

3.1. Interference composition with closure

The first condition for a process to be self-transformative is that it must accomplish a special composition, namely, a composition with interferences that is closed in a looped way. To elucidate this kind of composition it is first essential to define an appropriate mereological framework. Here, I will mainly rely on Seibt (2009, 2015).

3.1.1. Do classical extensional mereologies always work?

Processes are complex, they have parts (Rescher 1996, 2000). Hence, to analyze them we need a proper theory of parthood relations, namely, a mereology.[13] Classical extensional mereologies may be the natural tool for it, where "classical extensional mereologies" refer to mereologies that accept transitivity, irreflexivity and asymmetry as basic properties of the relation *is-a-proper-part-o*f, and accept also some specific decomposition principles such as strong

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[12] No surprise that the conditions defining a sort of processes are composition and function. Remember the definition of process above mentioned (Rescher 1996, 2000).

[13] "Mereology (from the Greek μεϱος, 'part') is the theory of parthood relations: of the relations of part to whole and the relations of part to part within a whole." (Varzi 2019).

supplementation and the proper parts principle.[14] However, classical extensional mereologies don't work in all cases. I claim that they are suitable for analyzing temporal and spatial parts.[15] Nevertheless, they encounter difficulties when analyzing process parts. I will provide three main reasons.

First, as mentioned before, classical extensional mereologies are useful to analyze temporal and spatial parts, but not all processes can be completely determined spatio-temporally. For example, it may be possible to determine spatio-temporally things like cups, tables, or cats, but it is hard to determine other ever-changing processes like windstorms, earthquakes, or thoughts in the same manner.[16]

Second, classical extensional mereologies accept transitivity. However, functional parts do not always fit into transitivity. My hand is part of me, I am part of society, but my hand is not part of society. The screw is part of the door, and the door is part of the house, but the screw is not part

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[14] No time here to largely develop extensional mereologies (cfr. Simons 1987 and Varzi 2019). Here I will define them as the mereologies that accept transitivity, irreflexivity and asymmetry about *proper part* relationship. Extensional mereologies also accept strong supplementation and the principle of proper parts. The principle of proper parts means that if two entities are identical, they share the same parts and, viceversa, if two entities have the same parts, they are identical. It comes from transitivity, irreflexivity and the acceptance of strong supplementation (Simons 1987).

[15] Even there, we should consider limitations with the concept of simultaneity, derived from the special theory of relativity.

[16] Cups, tables and cats are things in the sense of having a low spatial automerity and a high temporal automerity. See Seibt (2009).

of the house, at least not in a relevant way.[17] Aspects such as functional relevance or type of function must be settled before applying transitivity to functional parts, unlike what happens with spatial or temporal parts.

Third, classical extensional mereologies typically, by being associated with temporal or spatial parts, preclude closed looped compositions such as figure 1 (see Simons 1987). However, these kinds of compositions are not completely alien to processual analysis. For example, the stretched bow is based on two conjoint processes that share the very same parts, namely, the tensional effect of the body in the string and the tensional effect of the string in the body.[18]

In sum, classical extensional mereologies do not always work. In particular, they are not useful for analyzing functional parts, such as those that are the constituents of processes. So, to analyze processes, we need a non-classical mereology. The next section will attempt to sketch a possible alternative.

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[17] See Seibt (2015) for these and other similar examples. Seibt distinguishes functional proper parthood and extensional proper parthood relations and defends that transitivity applies, strictly speaking, only on the second one.

[18] More on these kind of examples in next sections.

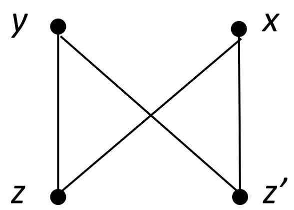

Fig 1: A composition where *x* and *y* are not the same, even though both have the same parts, namely, *z* and *z'*. This composition violates the principle of proper parts. Nevertheless, this kind of composition may be useful for self-transformative processes.

3.1.2. An alternative non-classical mereology

There's something about classical extensional mereologies. Processes are complex and causally/functionally determined, therefore we analyze them using functional parts. However, extensional mereologies are tailored towards spatio-temporal (non-functional) parts. Hence, they are not the best option for processes. Two main options pave the way towards non-classical mereologies: either giving up on irreflexivity (Cotnoir & Bacon 2012) or abandoning transitivity (Seibt 2015). I have just shown some reasons why transitivity does not always work for functional parts. So, I believe that the best option is the last one. Now, I will briefly sketch some aspects of a non-classical mereology for the functional proper parthood relation (inspired by Seibt 2015).

Let fPP be the functional proper parthood relation between x and y, where fPPxy means that x is a (functionally determined) proper part of y. First, the relation fPP is asymmetric:

$$\mathrm{fPP}xy \rightarrow \neg \mathrm{fPP}yx \qquad \text{(asym)}$$

This stems from the fact that the relation *is-a-proper-part-of* always requires some hierarchy, that is, it is not applicable between equals. This also emerges from the very nature of processes.[19]

Second, from (asym) we conclude that the relation fPP is also irreflexive[20]:

$$\neg \mathrm{fPP}xx \qquad \text{(irref)}$$

This property can be reformulated by means of the *corollary of insufficient granularity*. According to this corollary, if we assert that a process constitutes a functional proper part of itself (i.e., it can alter itself), we should instead pursue a more extensive decomposition to identify the functional proper parts that explain this deceptive reflexivity. For example, if I say that the world self-regulates itself, I should

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[19] "Whitehead describes the features of processual relatedness particularly important to our purpose as: causal, asymmetrically internal character of the relations, and the notion of a causal universe. [...]

Causality is asymmetric in a way that is deeply involved in the nature of a process." (Hansen 2004, p. 155).

[20] A property is called to be asymmetric if and only if it is antisymmetric and irreflexive.

find specific processes that justify this self-regulation such as water cycle's components, ecosystemic feedbacks, etc.

Third, as I said before, the relation fPP is not necessarily transitive. To check its transitivity, the relation fPP must be well-determined: "[T]he depth of parthood chains where the inferential pattern of transitivity can be applied depends on the specification of the part-relation involved (spatial, temporal, material, functional, etc.) and on the kind of relata" (Seibt 2015, p. 177).

How can this functional proper parthood be determined? There is surely more than one way. One of them is by using the notion of *interference* (Seibt 2009). An interference is an interaction between processes where, as result, a new process appears, and this is not merely the sum of compositional processes. An interference has the following components:

- Interfering parts: a set of processes that interfere to produce a new process.
- Interference focus: the whole interference process, whose parts are the interfering parts, and a product.
- Interference product: the new process that is not contained in interfering parts but is a part of the interference focus.

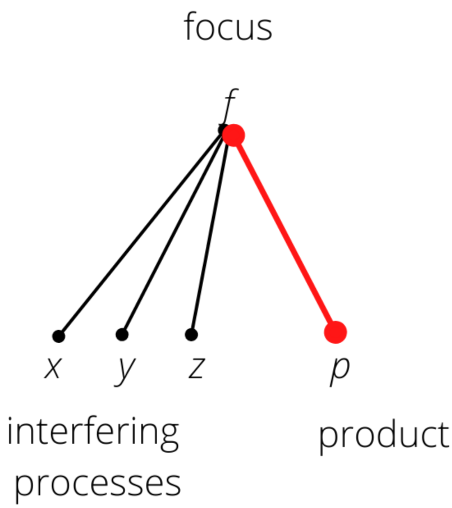

Fig 2: An interference according to Seibt (2009). Interfering processes *x*, *y* and *z* produce a new process *p*. The focus *f* represents the whole interference. Note that *is-a-proper-part* relation is differently determined for the interfering processes and for the product.

It is important to realise that the notion of interference defines a certain determination on functional proper parthood. In other words, parthood relationship between *x* and *f* and parthood relation between *p* and *f* are not similarly determined in fig. 2. On the contrary, they have different functional determinations. The first one is an *interfering* part relation while the second one is a *product* part relation. Let's call the first one $fPP^{i}xf$, that is, functional proper parthood as interfering processes, and the second one $fPP^{p}xf$, that is, functional proper parthood as product.[21]

Four additional brief points should be metioned. (1) I stay on unique step relations (shallow relations), which are asymmetric, irreflexive and non-transitive, as said on the above briefly sketched mereology. (2) Strong supplementation and, consequently, the principle of proper parts (if applicable) do only apply for homogeneous fPP relations. That is, they apply separately for fPP^{i} or for fPP^{p}. This means that fig. 3a is not legitimate in this non-classical mereology, but fig. 3b is. (3) So, this non-classical mereology encourages *fabric* compositions instead of the spanning tree compositions that are common in classical mereology. And (4), however, this non-classical mereology does not substitute classical mereology in all cases. Classical extensional mereology remains applicable to spatio-temporally determined parthood relations.

[21] Note that the term "product" does not mean that interference processes should be considered as productive processes. They mainly remain transformative. In this context, "product" is a technical term and refers to the fact that there is not a mere *sum* of parts, but something new emerges.

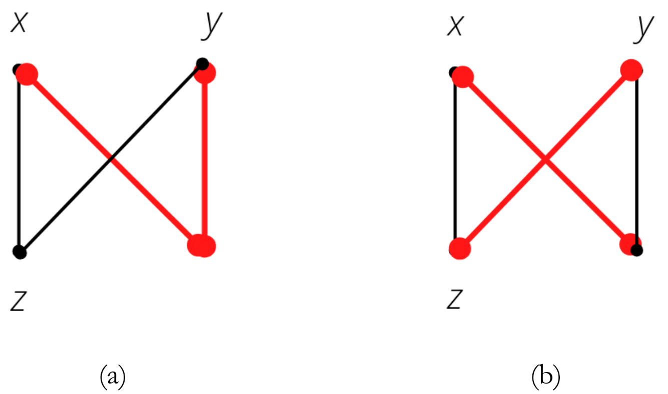

Fig 3: Two problematic compositions on classical extensional mereology that are differently evaluated on non-classical mereology. Fig. 3a (on the left) violates this non-classical mereology while fig. 3b (on the right) does not, because of heterogeneity on part relations.

3.1.3. A composition for self-transformative processes

There are two more steps left to completely define a candidate composition for self-transformative processes. First, let's define chained interference as two (or more) interferences where the product of the preceding interference is part of the interfering processes of another subsequent interference. I call this kind of composition "saw tooth", because of its distinctive shape.

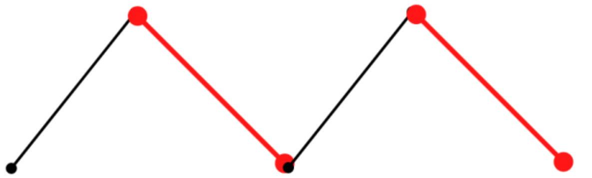

Fig 4: Interference pattern on a chained (or saw tooth typed) interference composition. Here an interference product is part of the interfering processes of another interference. There may be other interfering processes, though they are not depicted here.

Let's also define closure on a chained interference as the existence of a loop (or more than one loop) on a chained interference composition. As earlier mentioned, "closure" does not mean isolation, but merely that the product of a subsequent interference is also part of the interfering processes of a preceding interference.

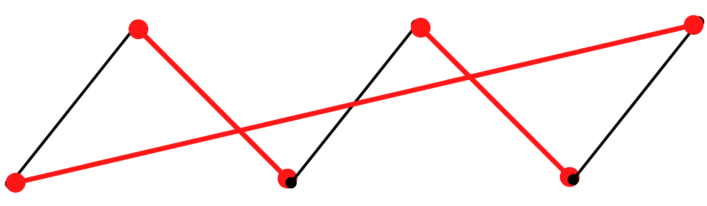

Fig 5: Interference pattern on a chained interference composition with closure.

Now it is possible to define the composition of self-transformative processes. This composition has a closure on a chained interference pattern processes. This composition is one where there is a closure on a chained interference pattern. The case of the body and the string in the stretched bow illustrates this beautifully. Here, there are two interferences whose parts are the body and the string of the bow, namely:

- An interference from the body into the string, thereby creating tension.
- An interference from the string into the body, causing it to stretch.

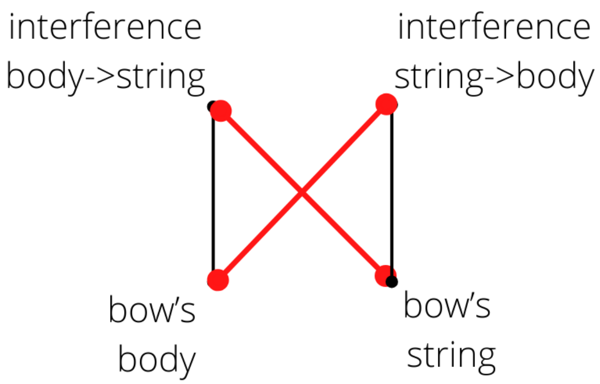

Fig 6: Simplified process composition for a stretched bow, where two mutual interferences are displayed. This exemplifies one of the permitted compositions within non-classical mereology. While alternative

compositions may exist, this one is aimed to depict the mutual stretching between body and string.

The system formed by a spring and a mass suspended from it has also the very same composition of mutual interference. In this case the mass affects the spring by causing it to stretch, and simultaneously, the spring affects the movement of the mass by constraining it. So, both systems (the stretched bow and the spring-mass) show compositions of interference with closure.

However, self-transformativeness is not confined solely to natural systems. Artificial systems like those of the theory of control are based on feedback loops which resemble the chained interference compositions referred above. This is the case of the inverted pendulum control system.[22]

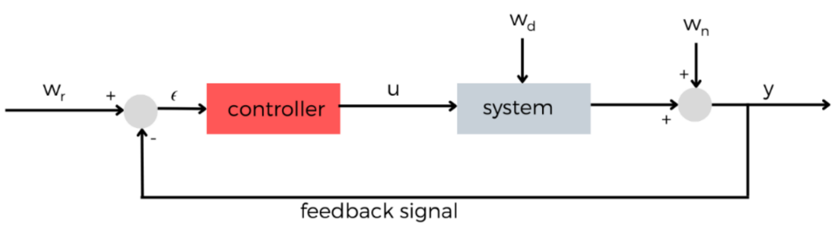

Fig 7: Feedback model for controlling an inverted pendulum. Here *y* represents sensor signals, *u* represents the controller signal, w_r represents the reference signal, whose difference with *y* results in the error ϵ, and w_d and w_n are the external

[22] See Brunton and Kutz (2019, p. 327)

perturbation signal and the noise, respectively. This composition resembles the chained interference composition with closure represented in fig. 5. Adapted from Brunton & Kutz (2019: 327)

Compositions with closure, though, may not be sufficient to completely define a self-transformative process. For example, a billiard ball hitting another billiard ball… hitting the first one is not the kind of process we would like to emphasize. An additional property is required for a process to be considered self-transformative.

3.2. Closure on modulation

Systems can be described by variables, and variables change through time. When the change of a variable depends on another variable, we say that the second variable affects or (to put it more technically) *modulates* the first variable. When those variables describe two different processes, we say that a process *modulates* another process.

For the sake of comprehensiveness, let's consider an example. According to Lotka-Volterra equations, the number of predators affects (or modulates) how the numbers of preys will change in time and vice versa:

$$dx/dt = x(\alpha - \beta y)$$
$$dy/dt = -y(\gamma - \delta x)$$

where x and y are the numbers of preys and predators in a given ecosystem (expressed by population density), α describes the growth rate of preys, γ represents the death rate of predators and β and δ represent the effect of predators on preys and the effect of preys on predators, respectively.

The whole system is self-regulated: there is a closure on modulation. The number of predators narrows the growth of prey population and, inversely, the number of preys raises the growth of predators. There is also a self-modulation for each variable. The growth of predators depends also on the number of predators, and the growth of preys depends on the number of preys. Thus, reproductive constraints and competition over resources are also reflected in these equations. Finally, α, β, γ and δ are positive and they capture the fact that there are other external processes (climate, terrain, diseases, idiosyncratic factors) which can also affect the whole self-regulatory process.

The variables that describe a system can be quantitatively determined (as stated on Lotka-Volterra equations) or qualitatively determined (as we know from conscious experience). In the remainder of this section, I am going to characterize what closure on modulation is for quantitative variables. I will use a mathematical framework, namely, dynamical systems theory. Unfortunately, we currently lack a framework for qualitative variables. In the following section I will apply quantitative modulation for explaining a particular theory of consciousness and introduce the need of extending this idea to experiential parts, that is, to the qualitative realm.

3.2.1. Closure on quantitative modulation

The most developed formal representation of closure on quantitative modulation is given by differential equations.[23] However, to represent self-modulation mathematically, a more general framework would be better. The framework I am going to choose is nonlinear dynamics (Strogatz 1994). First, I will provide a minimal introduction to this framework and then I will explain self-modulation according to it.

For Strogatz (1994, p. 6) a dynamic system that evolves in continuous time can be expressed by the following canonical form:

$$\mathrm{d}x_1/\mathrm{d}t = f_1(x_1, x_2, \ldots x_n)$$
$$\ldots$$
$$\mathrm{d}x_n/\mathrm{d}t = f_n(x_1, x_2, \ldots x_n)$$

where $x_1, x_2, \ldots x_n$ represent relevant quantitative aspects of the system and f_i represents the dynamics or function that describes the change of a given variable x_i.

This canonical form explicitly shows two noteworthy aspects about dynamical systems:

(a) Dimension: the dimension of a dynamical system is the number of (time dependent) variables needed to characterize the state of the system. For example, the system represented by the canonical

[23] Regarding this topic, Rescher claims that "the fact is that neither the logic of object and predicate nor even the grammar of subject and verb prevail in the language of nature. Rather, it is the mathematical language of differential equations that best represents its language of process." (Rescher 1996, p. 92)

form above is *n*-dimensional, because it is described by *n* time-dependent variables ($x_1, x_2 \ldots x_n$). This is also called the dimension of the "phase space" (Strogatz 1994, p. 9), and it should not be confused with the dimensions of physical space (typically, three).

(b) Nonlinearity: a dynamical system is linear if all functions $f_1, f_2, \ldots, f_n$ are linear, that is, if it happens that, in all of them, the variables x_i appear to the first power only (for example, $a_1x_1+a_2x_2+\ldots+a_nx_n$). A dynamical system is non-linear if any of the functions $f_1, f_2, \ldots, f_n$ is non-linear, that is, if any of them contains products (x_ix_j), powers (x_j^3) or other specific nonlinear functions (such as $\sin x_i$). Analytically speaking, this aspect is paramount. A linear system is easier to decompose and analyze. In contrast, nonlinear systems are complex and hard to solve.

These two aspects properly describe the complexity in the analysis of a given dynamic system. Systems with only one dimension cannot oscillate.[24] Conversely, systems with high dimension or high nonlinearity present complex behaviours and are very hard to characterize. Brunton and Kutz (2019) emphasize that it is possible to operate on systems by transformation of variables to decrease nonlinearity, but only at the cost of increasing dimension

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[24] "Fixed points dominate the dynamics of first-order systems, [...] trajectories are forced to increase or decrease monotonically, or remain constant [...] the phase point never reverses direction.

[...]

Hence there are no periodic solutions to $\dot{x} = f(x)$." (Strogatz 1994, pp. 28-29).

(and vice versa). Therefore, a trade-off exists between these two aspects.[25]

Although the notion of closure in modulation is not explicitly mentioned in dynamical systems theory, it follows quite directly from the canonical form.[26]

Let's consider a dynamical system with one dimension, represented by this canonical form:

$$dx_1/dt = f_1(...,x_1, \ldots)$$

In this system, the variable x_1 is self-modulated. The way it changes in time depends on its own current value. Note two points. First, if a system is one-dimensional and self-modulated, then no oscillation is expected.[27] Second, this kind of modulation expresses the relationship of a variable

[25] See what they assert about the Koopman operator: "Koopman operator theory has recently emerged as an alternative perspective for dynamical systems in terms of the evolution of measurements g(x). In 1931, Bernard O. Koopman demonstrated that it is possible to represent a nonlinear dynamical system in terms of an infinite-dimensional linear operator acting on a Hilbert space of measurement functions of the state of the system. This so-called Koopman operator is linear, and its spectral decomposition completely characterizes the behavior of a nonlinear system [...]. However, it is also infinite-dimensional, as there are infinitely many degrees of freedom required to describe the space of all possible measurement functions g of the state." (Brunton & Kutz 2019, p. 300).

[26] Nevertheless, the notion of closure in modulation is not novel. It is very close to the notion of *coupling* (Strogatz 1994). Coupling between variables is a form of closure on modulation.

[27] See footnote above (Strogatz 1994, pp. 28-29).

to itself, not an inference relation between a process and itself. So, irreflexivity is not violated, and for now, there is no need to apply the corollary of insufficient granularity.

Similarly, let's have a 2-dimension dynamical system represented by the following canonical form:

$$\mathrm{d}x_1/\mathrm{d}t = f_1(..., x_2, \ldots)$$
$$\mathrm{d}x_2/\mathrm{d}t = f_2(..., x_1, \ldots)$$

This system presents a kind of closure on modulation that we can call cross-modulation. The change in time of both variables is intertwined in a mutual dependence.

Finally, let's consider an *n*-dimensional dynamical system where we can take three (or more) variables x_i, x_j, x_k with the following relationship:

$$\mathrm{d}x_i/\mathrm{d}t = f_i(..., x_j, \ldots)$$
$$\mathrm{d}x_j/\mathrm{d}t = f_j(..., x_k, \ldots)$$
$$\mathrm{d}x_k/\mathrm{d}t = f_k(..., x_i, \ldots)$$

Here we have a general expression for modulation with closure.

This characterization of closure on modulation can be extended from continuous time to discrete time variables. A continuous time variable $x(t)$ takes values at any point of time. On the contrary, a discrete time variable $<x>_i$ takes values only on discrete points of times, namely, on each iteration ($i=1,2,3\ldots$). That is the case, for example, of the value obtained in a calculator if repeatedly pressed the cosine button (Strogatz 1994, p. 348). For this reason, discrete dynamical systems are also called iterated maps.

Just like differential equations, iterated maps accept closure on modulation. This is an expression of modulation with closure on iterated maps:

$$<x_i>_{n+1} = f_i(\ldots,<x_j>_n, \ldots)$$
$$<x_j>_{n+1} = f_j(\ldots,<x_k>_n, \ldots)$$
$$<x_k>_{n+1} = f_k(\ldots,<x_i>_n, \ldots)$$

The closure on quantitative modulation can describe numerous systems in reality. Closure on modulation is used to model the evolution of all kinds of dynamical systems, encompassing both natural and artificial systems. To begin with, the stretched bow needs descriptions based on differential equations with closure (see Kooi 1981 and Zaniewski 2009). However, the details of those descriptions are quite intricate, they are based on the bow-arrow-archer system and they are very constrained by the models used in each case.[28] For the sake of clarity, I will stick to a less complex but very eloquent example of closure on quantitative modulation, also taken from the realm of physics.

The simple harmonic oscillator, consisting of a spring and a mass suspended from it (and supposing no friction) clearly illustrates the closure on quantitative modulation. This movement is described by Hooke's law:[29]

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[28] For example, Kooi describes a bow moving in "a flat plane" and "symmetric with respect to the line of aim". The bow can only have a slight "recurve" on the limbs (Kooi 1981: 120). Zaniewski accepts most of those constrains. However, while Kooi models the arrow as a flexible shaft, Zaniewski models it as rigid (Zaniewski 2009: 308).

[29] See Strogatz (1994: 124).

$$m \, d^2x/dt^2 = -k \, x$$

Where m is the mass, x is the displacement of the mass from equilibrium point and k is the spring constant, always positive. Here, we really have a two dimensional cross-modulated system we can express with the following canonical form:

$$dy/dt = -k \, x/m$$
$$dx/dt = y$$

Which confirms the previous claim that any oscillatory movement (such as the mass suspended from a spring) requires at least two dimensions.

Artificial systems like those of control theory show the same kind of closure on quantitative modulation. In other words, if we aim to quantitatively control the behaviour of a system described by a closure on modulation of its variables, we need to act on the mechanisms that intervene in these particular modulations.[30] This stresses the relevance of self-transformativeness.

By now I have defined what self-transformativeness is and I have exemplified it on different realms of reality, ranging from natural to artificial systems. Systems like the stretched bow, the spring-mass, and the inverted pendulum fulfil the two requirements to be considered self-transformative, namely, having an interfering composition with closure and being quantitatively describable by self-

[30] No time here to show how a system described by a quantitative modulation with closure (such as the inverted pendulum) needs self-transformative solutions to be controlled. For a detailed description, see Brunton & Kutz (2019, pp. 327-328)

modulated variables. In the subsequent section I will extend the application of self-transformativeness to the realm of conscious experience.

4. Consciousness and self-transformativeness

Self-transformativeness, as defined above, is prevalent in many aspects of reality. It is easy to encounter it in natural environments, but it is also present in artificial devices. It appears when describing population growth, but also in simple physical phenomena such as the stretch bow and the movement of the spring and a mass. We can find it in large organisms but also in tiny ones, as long as they all use self-regulatory (hormonal, neural, vigilance) mechanisms that are based on closed-loop interfering systems and can be described by self-modulating variables. Finally, it is possible to find its vestiges in interactions between humans and the environment (Wiener 1948, Shapiro 2011).[31]

My claim here is that processes, and more specifically, self-transformativeness, may play a significant role also when explaining consciousness. More precisely, theories of consciousness seem to require processual self-transformative aspects at one point or another, especially when they are stressed about their internal mechanisms, and the introduction of those aspects is not trivial but essential for the development of those theories.

[31] Loop interactions are fundamental for cybernetics and for extended cognition.

Traces of self-transformativenesss seem to appear in a wide array of theories about consciousness.[32] Take, for instance, biologically rooted (neuroscience-centric) theories. They state that reentrant or recurrent neural networks, where top/down and bottom/up processes converge, are essential to explain conscious experience (Edelman 1989; Varela, Lachaux et al. 2001). Even when the theories differ, recurrent neural networks seem to be pervasive. This is the case for the Global Neuronal Workspace Theory (Dehaene, Changeux and Naccache 2011), where conscious experience is related with long-spread recurrent networks involving different brain areas such as prefrontal and parietal areas. And it is also the case for Lamme (2010), who claims that locally restricted recurrent processing may be sufficient for some particular types of phenomenal visual consciousness (such as fragile visual short-term memory).

However, here I will focus on informational theories. One of the most influential informational theories is the Integrated Information Theory (IIT).[33] There are many cues

[32] Aramendia (2022) distinguishes four main kinds of theories about consciousness: (1) representational theories (which may be first order —Drestke 1995, Tye 1995—, high order —Rosenthal 2005— or same order representational theories —Kriegel 2009—), (2) informational theories (such as Global Workspace Theory —Baars 1988— and Integrated Information Theory —Tononi 2008—), (3) biological theories (such as Koch 2004, the Global Neuronal Workspace Model —Dehaene, Changeux and Naccache 2011—, Lamme 2010 or Bachmann 2000) and (4) physical theories (quantum based theories such as Hameroff and Penrose 1996). I sustain that there are self-transformative aspects in the first three kinds, that is, in representational, informational and biological theories (Aramendia 2022).

[33] Tononi (2008); Balduzzi & Tononi (2008); Oizumi, Albantakis and Tononi (2014).

that IIT and, specifically, its last version 3.0 (Oizumi, Albantakis and Tononi 2014, Tononi & Koch 2015) shows remarkable self-transformative aspects.

Here, I am not going to defend IIT against other alternatives. This approach has pros and cons, and unfortunately, I have no time to delve into this interesting issue, so for now, I'd rather remain neutral.[34] My aim here is different, namely, *to defend the idea that IIT, when closely examined about its particular processes and mechanisms, shows self-transformative aspects and that these aspects are not trivial, but essential*. Being a mathematically well-founded theory, IIT provides a clear example of quantitative self-modulation.

4.1. Integrated Information Theory and self-transformativeness

As mentioned above, I am going to argue that self-transformative processes are essential to some informational theories about conscious experience, namely, the IIT. I will proceed by showing two main points. First, I will briefly outline the mathematical framework of IIT, which is based on the notion of *(in)formation* as structure, and I will show that the mechanisms underlying the complex systems specific to IIT are based on a type of dynamical systems I discussed when dealing with modulation, namely, discrete dynamical systems (also known as iterative maps). Second, I will show that the discrete dynamical systems that are the theoretical core of IIT (particularly, in version 3.0) do need self-modulation in an essential way and, therefore, self-

[34] Pseudo-panpsychism is mostly its main charge, but not the only one. It is also alleged that the axioms that constitute the core of this theory are not complete. For more on this engaging discussion, see Tononi & Koch (2015) or Bayne (2018).

transformative processes constitute an essential part of this theory.

According to IIT, conscious experience exists (as a particular non-reducible thing) and is fundamentally a conceptual structure, namely, *(in)*formation with a certain level of integration, within a complex system of elements (Tononi & Koch 2015, p. 9). The quale of the experience is given by the structural relations that exist and *(in)forms* those elements. The core of this theory comes from five self-evident claims about experience, which are called axioms, and their corresponding physical stipulations about the systems that can account for them, which are called postulates. Here I will focus on two of those axioms. (1) Conscious experience is specific, meaning that it is the way it is and not otherwise. It has phenomenal distinction. Particularly, experience *(in)forms*, that is, has a composition that makes the difference. For example, the experience of seeing a triangle, seeing a red apple, or listening to a symphony are specific and differ from each other. (2) In spite of (1), conscious experience always manifests with an aspect of unity. This means that there are no isolated parts of the experience. On the contrary, all parts are *integrated* and constitute this particular conscious experience and no other.[35]

These axioms lead to the postulation of certain facts about the physical systems that may account for consciousness. The systems should be complex, that is, they are formed by elements (supposedly, neurons) that must be related to each other. The specific way the elements relate to

[35] The first one is the axiom of information and the second one is the axiom of integration. See Oizumi, Albantakis and Tononi (2014, pp. 2-3). See also Tononi & Koch (2015, p. 6).

each other is called the mechanisms of the complex system. These mechanisms operating over time have causal powers, that is, govern, define, and constrain the future states of the elements that constitute the system and make them be in a particular way and no other (information). On the other side, the causal powers of these mechanisms also have a specific mode of operation, namely, they integrate, which means that there is no way to split the system in two or more parts without dramatically affecting those causal powers (integration).

Let's consider an oversimplified example of a complex system which may have a small level of information and integration and, hence, of consciousness (according to IIT). This is a system composed of three bistable elements (A, B & C) governed by three simple mechanisms defined as logic functions (OR, AND & XOR).

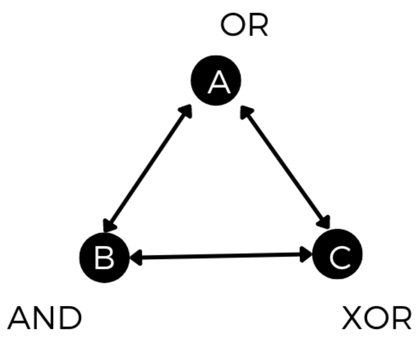

Fig 8: An oversimplified complex system with three elements A, B and C related by three mechanisms. Adapted from Oizumi, Albantakis and Tononi (2014).

It is possible to formalize the causal powers of the mechanisms that govern this system as follows:

$$<A>_{n+1} = \mathrm{OR}(<B>_n,<C>_n)$$
$$<B>_{n+1} = \mathrm{AND}(<A>_n,<C>_n)$$
$$<C>_{n+1} = \mathrm{XOR}(<A>_n,<B>_n)$$

Two key notes about this system. First, it has the very aspect of a dynamical system as presented above, only that the variables in this case are time discrete and not continuous in time. These systems are well-known in dynamical systems and are called iterated maps (Strogatz 1994). Second, the dynamics represented by the above system and its formalization has the shape of a system with closed modulation. Namely, it is a three-dimensional system where all variables are modulated by each other:

$$<A>_{n+1} = f_1(<B>_n,<C>_n)$$
$$<B>_{n+1} = f_2(<A>_n,<C>_n)$$
$$<C>_{n+1} = f_3(<A>_n,<B>_n)$$

Is this just a coincidence or does it reflect a pattern that happens in all complex systems that account for conscious experience? It turns out that it is not a coincidence, as IIT clearly states when it identifies what the “zombie feed-forward networks” are:

> Another corollary of IIT is that certain structures do not give rise to consciousness even though they may perform complicated functions. Consider first an "unconscious" photodiode. […]

> The same lack of feed-back that disqualifies the unconscious photodiode can be extended, by recursion, to any feed-forward system, no matter how numerous its elements and complicated its connectivity. (Oizumi, Albantakis & Tononi 2014, p. 19).

Thus, extremely complicated structures can be unconscious if they lack feedback. Conversely, oversimplified structures (such as fig. 8) can account for conscious experience if they have an appropriate feedback structure.

To summarize, I have hopefully shown two key points. First, that feedback loops in the characterization of complex systems proposed by IIT imply closure on modulation of discrete time variables. Second, that, within the framework of IIT, feedback loops are a requirement for the complex system to be conscious. As a result, closure on modulation (which represents a self-transformative aspect) becomes essential for having conscious experience in IIT.[36]

To conclude, two remarks. First, feedback and integration of information are not the same thing. It is perfectly possible to imagine a highly integrated system lacking feedback.[37] Thus, feedback is an added condition for

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[36] The question remains unanswered as to whether IIT requires compositions with closure for conscious experience. This hinges on the interpretation of the nodes existing in the complex system, an aspect that is not definitively settled in IIT. If nodes are taken to be neurons (that is, if a neural interpretation of IIT is adopted), then the composition with closure is also implied.

[37] For example, a complex system with a single neuron for integration.

integrated information in IIT. One reason may be that it is relevant for resilience on neural systems.

Second, this requirement of IIT (the need of feedback loops) does not equate IIT with other recurrent theories such as Lamme's or Global Neuronal Workspace Theory. Those theories are biologically established, while IIT is (in)formationally based. In IIT, the whole structure of the system is what defines the quale, and not a particular neural activity. (See Oizumi, Albantakis & Tononi 2014 and Tononi & Koch 2015.)

4.2. Qualitative self-modulation

Integrated Information Theory is vulnerable to a critique about internal consistency, in the sense that it does not go far enough with its own axioms and postulates. It accepts that conscious experience has (phenomenal) parts[38], and it also acknowledges that those parts can only be parts in attention to their causal powers[39]. Nevertheless, it seems that the phenomenal character of those parts has no relevant role or, at least, it does not appear in a very sharp way in the conceptual framework described by the theory. The definition of *quale* as a single conceptual structure for

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[38] This is the axiom of composition. "Consciousness is structured: each experience is composed of many phenomenological distinctions, elementary or higher order, which also exist. Within the same experience, for example, I may distinguish a book, a blue colour, a blue book and so on." (Tononi & Koch 2015, pp. 5-6)

[39] "This is the postulate about integration. "[I]ntrinsically irreducible […] implies that every part of the system must be able to both affect and be affected by the rest of the system." (Tononi & Koch 2015, p. 8)

phenomenology just exacerbates this problem.[40] Under these circumstances it is hard to give rise to something like a phenomenology.

This kind of critique is extendable to some other theories about consciousness. This may be because the processual aspect of conscious experience has not received enough attention and terms such as "state", "mechanism" or "immediacy" still retain a heavy metaphysical burden. What is more, while the quantitative self-modulating aspects of consciousness are easily recognisable (especially from the neural perspective, as reentrant and looped networks), there is no counterpart on the qualitative realm.

Now I will attempt to sketch some brief lines about what may constitute a scenario for qualitative closed modulation. When speaking about qualitative modulation with closure, I refer mainly to a pair of main ideas: (1) that experiential parts of a given experience can affect (modulate, change) other experiential parts of the very same experience and (2) that this affection happens in a looped way.

Regarding the first idea, we can distinguish two ways an experiential part can affect another part within the same experience. First, it may be agonistic, when the experiences nullify one another. For example, listening to relaxing music may in some circumstances mitigate anxiety or pain (Krishnaswamy & Nair 2016). Moreover, some experiences are completely incompatible with other experiences, as we can infer from conscious switching when seeing the Necker's

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[40] "Altogether, the elements of a complex in a state, composed into higher order mechanisms that specify concepts, form a *conceptual structure* that is *maximally irreducible intrinsically*, also known as a *quale*." (Tononi & Koch 2015, p. 9)

cube or on binocular rivalry.[41] In both cases, it is hard to attribute the switching to changes in stimuli, as long as those stimuli remain constant. Second, it may be non-agonistic, when both experiences can coexist. For example, melancholy or depression may tinge the perceptions of a given subject, while meditation may help to control her conscious states.

Regarding the second idea, the experiential parts that constitute a particular experience can indeed affect each other in a looped way. Rather than an enigmatic phenomenon, this can be crucial when comprehending experiences and experiential parts. Here, I will just mention one example. Experiences are *particular*, in the sense that they constitute *this* experience and no other. Let's take, for instance, the experience of seeing a landscape. Seeing a landscape is not just a representation of the external world (like a painting or a photograph) nor a representation of me being in the world. On the contrary, it has also another phenomenal part, namely, a feeling of this *particular* moment and this *particular* experience. When talking about consciousness, no assumptions should be made. Everything is to be explained. Thus, we do need to explain the *particularity* as a phenomenal part of the experience, namely, a part that is created by the experience while it affects the experience as a whole. Self-modulation is precisely the kind of conceptual tool that deals with parts of the experience such as particularity.[42]

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[41] On Necker's cube the switching happens several times and cannot always be attributed to changes in visual focus. For binocular rivalry on animals' perception, see Logothetis & Schall 1989; Leopold & Logothetis 1996; Blake & Logothetis 2002.

[42] Other experiences may also benefit from this kind of analysis. This may be the case of non-paradigmatic experiences in everyday

Conclusions

In this paper, I have employed the processual approach to analyze conscious experience. First, I have argued that a processual approach is not only justified but also necessary when dealing with conscious experience, and that it is necessary not only from a neurophysiological standpoint, but also from a phenomenological perspective. Conscious experience, as every process, is complex, functionally determined and unfolds over time with a significant dimension.

Secondly, I have revisited an old conceptual tool, namely, self-transformative processes, for the analysis of conscious experience. Self-transformative processes are processes whose parts interfere between them in a looped way and whose variables modulate themselves with closure.

Thirdly, I have emphasized the idea that the Integrated Information Theory of consciousness, if stressed about its internal mechanisms, does need self-transformative processes. Self-transformative processes lie at the very core of conscious experience for the Integrated Information Theory. This does not mean that self-transformativeness and consciousness must be equated, nor that one ensures by itself the other. In addition, if self-transformative processes are deeply involved in conscious experience, they should do it in two ways. First, in a quantitative way, as can be proved in biologically and informationally rooted theories of consciousness. Second, in a qualitative way, at least when all processual properties are seriously taken.

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life, such as the certainty in perception, the tip-of-the-tongue effect, or the sensation of taking detours. (See Aramendia 2022).

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