# In search of lost time:
## Integrated information theory needs constraints from temporal phenomenology

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### Abstract

Integrated information theory (IIT) of consciousness proposes an identity between its causal structure and phenomenology. Through this assertion, IIT aims to explain consciousness by prioritizing first-person experience. However, despite its phenomenology-first stance, developments in IIT have overlooked temporality. As such, we argue that at present IIT's phenomenological analysis is incomplete. In this critique, we show how IIT takes a non-identical illusionist stance towards the experiences of continuity, flow, and extent of our experiences. Moreover, in isolating temporal grains of experience to a single timescale, IIT misses out on capturing the multi-scale nested nature of temporal phenomena. Hence, we contend that IIT needs an axiom for time, through which its causal structure can be refined to account for temporal experiences. Here, we propose an axiom to address these concerns. We conclude by discussing how IIT may need to be revised if our concerns hold true.

### Keywords

Consciousness · Integrated information theory · Phenomenology · Time

## 1 Introduction

Integrated information theory (IIT) of consciousness has become an established contender for explaining consciousness based on three key unique proposals in its manifesto (Oizumi et al., 2014). They are: (1) IIT asserts that a measure (phi, $\Phi$) that represents a system's ability to integrate and differentiate information can be used to measure the degree of consciousness of that system (the so-called consciousness-meter). (2) IIT identifies its causal conceptual structure with subjective first-person experience, essentially conjecturing a psycho-neural identity for consciousness. (3) Finally, IIT also claims to be a more parsimonious explanation of consciousness

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because it prioritizes phenomenology and hence constrains (via axioms) its causal structure by keeping phenomenology first.

IIT has been criticized on all three of these grounds in the past. There have been arguments that IIT's measure(s) can be arbitrarily manipulated by changing a system's design from a recurrent feedback loop to a feedforward structure (Aaronson, 2014; Doerig et al., 2019), or that IIT measures only network efficiency in the brain and not consciousness itself (Merker et al., 2021), or that IIT's consciousness meter entails or is somewhat consistent with panpsychism (Merker et al., 2021; Tononi & Koch, 2015). Furthermore, IIT's axioms are criticized for failing to account for phenomenology, being underdeveloped, heuristic-like, and being tautological in saying the same thing in different ways (Bayne, 2018; Merker et al., 2021; Pokropski, 2018, 2019). Oddly still, the phenomenology-first nature of IIT is used to defend against the theory being circular, with the circularity being broken apparently by grounding the theory in phenomenology (Negro, 2020; Tsuchiya et al., 2020). It has been previously argued, however, that IIT has no phenomenological grounding or framework around which it builds its theory (Pokropski, 2019). Perhaps nothing makes this more apparent than the absence of a cornerstone of phenomenological analysis, namely temporality (Husserl, 1964).

At the very heart of phenomenological analysis is the temporal horizon, which is the necessary and inherent breadth of our experience over time. For not only Husserl who called it the most important and difficult problem in understanding the phenomenology of conscious experience (Husserl, 1964), time has been at the center of phenomenology also for Kant, Heidegger, Hegel, Merleau-Ponty, Sartre, and James, and most recently Varela and Gallagher (Andersen & Grush, 2009; Dainton, 2010). In fact, it is hard to find a phenomenologist who does not think time is a fundamental aspect of conscious experience.

Perplexingly, however, temporal phenomenology literature and frameworks developed over three centuries remain absent from IIT. Not only has there been no place for temporal phenomenology in IIT (Kent & Wittmann, 2021), but also the work done by those mentioned above has not been incorporated into IIT. This is further reflected in the absence of any reference to these phenomenologists or their work on time in any of the main original papers of IIT (Oizumi et al., 2014; Tononi, 2004, 2008).

This paper is thus aimed at investigating and critiquing the phenomenology-first and identity claims of IIT, specifically from the perspective of temporal phenomenology. In this paper, we critique the lack of temporality in IIT and what this absence entails. We argue that IIT does not adequately account for phenomenology and consequently cannot justify itself as giving priority to or being identical with phenomenological experience. Moreover, in ignoring temporality both in and of experience (i.e. both time-consciousness and timing of consciousness), IIT misses out on constraining the purported temporal evolution of conscious content and its structure. The theory fails to make adequate use of the existing literature on the timing of consciousness as well as time-consciousness. Previously, IIT has

been criticized on these grounds by Kent & Wittmann (2021), where they point out the demerits of relying on a single time-point value of phi measured over narrow time scales ranging a few hundred milliseconds and thus falling short of explaining the gamut of temporal phenomenology of experience. We extend and add to their criticisms comprehensively in this paper.

Before moving on to making these arguments, we briefly discuss why temporality has an important status in understanding phenomenological experience. In the sections after this, we offer our specific criticisms of IIT. We point out several temporal properties lacking in IIT, for example, continuity, extent, nestedness, multiscale time, and direction. We argue that an absence of a phenomenological account of these phenomena in IIT renders it incomplete and in need of revision at best or falsified at worst. Finally, we conclude by proposing an axiom of time that may help the theory in accommodating key aspects of phenomenology and reworking its conceptual structure.

## 2   Why is temporality important for a phenomenological theory of consciousness?

Why should IIT or any theory of consciousness care about temporality? If there is any property of consciousness that can be argued to be common between a causal structure of experience and consciously experienced content, it is time (Cohen, 2011; James, 1890; Kent & Wittmann, 2021; Kiverstein, 2010; Kiverstein & Arstila, 2013; Phillips, 2010, 2014; Varela, 1999). To experience the color red, nothing in the causal structure underlying the experience of "red" itself has to be colored. This is not only true for color but other kinds of experiences as well; the causal structure of experiential states of emotion or hunger themselves are not emotional or hungry. However, it has been posited that the temporal evolution of content is isomorphic[1] to the temporal evolution of the structure that generates it (Dainton, 2008; Kiverstein, 2010; Phillips, 2010, 2014). That is, not only does our experience represent temporal properties, but the structure responsible for our experience has temporal properties of its own. By virtue of this, if one has to understand the relationship between a causal structure of experience and experience itself, one has to do it via temporality (Singhal & Srinivasan, 2021). Thus, if there is indeed something common between the vehicle and content of experience (as also claimed by IIT), time or temporality is the ideal starting point (or perhaps the only starting point).

Another reason why time has a special status in phenomenology is because of the experience of a "now" (James, 1890). A purported organizing principle of our experiences is that they occur in a manner that is both extended and present-like (Droege, 2009; Kelly, 2005; Pockett, 2003). Literature in phenomenology is resplendent with illustrations of experiences such as watching a bird glide across the sky,

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[1]For an opposing view, see Dennett & Kinsbourne (1992).

listening to an opera singer holding a note, tracking the feather's fall to the ground, pursuing a high-speed projectile in sports, etc. These experiences, at least, seem to occur over a continuous and extended time interval. More formally, an extended present-like organization of our experiences is accompanied by the ability to perceive order, duration, persistence, simultaneity, flow, succession, and continuity both within and between them (Kelly, 2005). These have been argued to be not only fundamental properties of consciousness but also necessary aspects of a phenomenological experience. Recent proposals (Singhal & Srinivasan, 2021; Varela, 1999; Windt, 2015) have argued that these temporal properties can be deployed to describe the necessary properties of consciousness and unify existing findings in the field under a 'minimal unifying model' approach (Wiese, 2020). To do justice and make use of the rich history of phenomenological analysis, IIT needs to account for these minimal properties of consciousness. This requirement is critically important for any theory that claims to be a phenomenology-first and structure-experience identity theory. In its current formalization (Oizumi et al., 2014), temporal phenomenology remains significantly ignored. In the following two sections, we show where and how time is missing in IIT and what are the implications of this for the theory.

## 3 Continuity

### 3.1 Phenomenology

A property of conscious experience that fails to be accounted for by IIT is the continuity or flow of experience. In a sole mention of temporal frameworks, it is claimed that IIT is parsimonious with a dynamic snapshot theory of time-consciousness (see Tononi & Koch, 2015, p. 16, also quoted below). According to this view, experience is made up of frame-like snapshots. However, unlike the traditional cinematic theory, where the snapshots are static, it allows for temporal information to be 'represented' in these snapshots (Phillips, 2017). Both these views nevertheless are against the naive view that our experience seems continuous because it is so. For instance, to represent motion, one could have a representation that itself changes or represents motion over an instant (like the speedometer in a car). IIT does not discuss the implications and motivations of choosing the latter.

To a skeptic, it appears that the choice of a snapshot was made of convenience since IIT's causal structure is a discrete state system and would require a discrete-time framework (Oizumi et al., 2014). The convenience only ends here. Quickly, IIT runs into a major philosophical complication, which is further exacerbated by the combination of two claims - one that of identity between structure and phenomenal experience (Oizumi et al., 2014); and the other of disallowing overlapping time windows (to avoid multiple causations) (Tononi & Koch, 2015). Being a phenomenology-first theory, IIT tries to incorporate the property of continuity by positing that experience is "seemingly" continuous even though it is a succession

of discrete snapshots, thus giving continuity the status of a mere illusion (see the quote below).

> The exclusion postulate requires that the set of mechanisms that specify one particular experience do so over the time window at which $\Phi$ reaches a maximum. If the next experience involves an over-lapping set of mechanisms, it would seem that, to avoid multiple causation, it should be specified over a non-overlapping time window. Accordingly, the seemingly continuous 'stream' of consciousness would actually be constituted by a discrete succession of 'snapshots', in line with some psychophysical evidence. Note that each snapshot has motion and other dynamic percepts associated with it. (Tononi & Koch, 2015, p. 16, footnote 11)

In taking an illusionist stance, IIT inadvertently hurts its own identity claim because now there is an illusion of continuity (still a phenomenological explanandum), which is no longer identical to IIT's causal structure.

Further, the exclusion postulate necessitates that our experiences are bound in isolation and encapsulated in their own 'time windows' (Tononi & Koch, 2015). To unpack the nature of the underlying temporal structure that IIT advocates, we consider three frameworks from time- consciousness literature: the cinematic, retentional, and extensional theories (for a detailed review, see Dainton, 2010). From a naive phenomenological viewpoint, if the structure of consciousness is claimed to be identical to experiential content (as in IIT), prima facie, one would opt for an extensional framework. Since the phenomenology of continuity is itself not contested, and if the identity must hold, it is essential that the underlying causal structure unfolds continuously as well. However, IIT surprisingly champions a cinematic framework. However dynamic the snapshots are, continuity still has no other way but to end up on a shelf of illusions. Furthermore, it is unclear what the phrase 'time-windows' means within a cinematic framework. Suppose it is the time-window at the end of which everything within the window is rendered conscious (Herzog et al., 2020). In that case, it is not clear whether the time window (or scale) selected is the one 'over which' or 'at the end of which' $\Phi$ reaches maximum.

One could argue that IIT entails a retentional framework where acts of consciousness are still momentary. However, it has to be noted that according to the Husserlian framework (Husserl, 1964), the content is still extended and has a non-uniform, tripartite temporal structure within a 'now'. This temporal structure is constituted by a primal impression of the momentary now together with retention of the just-past and protention of the immediate-future (Dainton, 2010). For example, Husserl (1964, p. 202) says: "But each such momentary perception is the nuclear phase of a continuity, a continuity of momentary gradated retentions on the one side, and a horizon of what is coming on the other side: a horizon of 'protention,' which is disclosed to be characterized as a constantly gradated coming." Such an account would mean that even though the acts are momentary, the con-

tent of the 'now' is not punctate but overlapping. A Husserlian conception of time poses a problem for IIT in two ways. One, IIT does not have an inherent temporal structure within a 'now'. Second, it does not allow for overlapping time windows to occur (Tononi & Koch, 2015). The latter has more serious implications in a cinematic framework because this makes it hard to explain the diachronic unity of consciousness, i.e., the unity of experience across time (Dainton, 2010).

Even the 'integration axiom' talks about a kind of integration that is synchronic in nature (integration of different contents at a discrete moment of experience (Tononi, 2015) but remains silent about the integration of content over time (Kent & Wittmann, 2021). We do not experience choppy snapshots but a continuous flow of experience. We experience change, succession, and persistence of a musical note held in time. Suppose the snapshots are dynamic and changes over the time window are still "represented". But if there is no overlap between two consecutive windows (or a mechanism connecting them), how would one explain the continuity of experience? Hence, the combination of claims made by IIT is not coherent enough to explain the phenomenology of temporal passage and continuity.

## 3.2   Transitions between contents of conscious experience

Any theory of consciousness not only needs to explain how one becomes conscious of something but also how within our consciousness things come to be, change, and disappear (Aru & Bachmann, 2017; Fekete et al., 2018). How do we go from perceiving one thing to perceiving something else? Surprisingly, proponents of IIT pay little attention to answering this question from phenomenology. As mentioned earlier, state transitions of experience for IIT are discrete and non-overlapping. It is important that IIT provides the rationale behind employing a discrete snapshot theory based on phenomenological evidence because the evidence for a discrete cinematic framework is not straightforward or self-evident at all. The phenomenological evidence should take precedence over computational tractability. It has been argued that the experimental data that apparently shows that perception is discrete could also be explained by assuming continuous models (Fekete et al., 2018; Piper, 2019). The existence of finite-length windows of integration does not necessarily imply that conscious experience is discrete in nature (Piper, 2019; VanRullen & Koch, 2003). In fact, theories that posit an isomorphic relationship between experience and the substrate and take phenomenology seriously are mostly extensional theories. For example, the Temporo-Spatial Theory of Consciousness (TTC) claims that the common currency between the brain's neural activity and dynamics of experience is the shared temporo-spatial properties between both (Northoff et al., 2020; Northoff & Huang, 2017), that is there is an isomorphic correspondence between temporo-spatial expansion of neural activity and that of phenomenal experience beyond the duration of the stimuli (see section 4.3, Northoff & Huang, 2017). The Reentrant Oscillatory Multiplexing (ROM) theory also proposes an extensional framework to explain the temporal properties of

experience like continuity via the sustainability of the phase coherence between multiple neuro-oscillatory frequency bands (Piper, 2019).

Consider this quote that highlights the discrete account of experience in IIT:

> According to IIT, an experience is identical with a maximally irreducible conceptual structure specified over itself by a complex of elements in a state, and it exists at a discrete interval of time at which cause-effect power reaches a maximum. It is important to establish how this relates to the dynamics of the elements of the complex at a faster time scale and to the temporal evolution of the states of the complex (Barrett and Seth 2011). It should be noted, however, that a complex in a state may specify a conceptual structure even when it is dynamically at a fixed point. (Tononi, 2015, footnote 22)

The often-made mistake in time-consciousness literature by cinematic models is to mix a succession of experiences with the experience of succession while they are regarded as phenomenologically different (Dainton, 2010; Hoerl, 2013). A cinematic model inescapably treats those two experiences as one, given that the snapshots are discrete and extension-less.

Assuming that IIT posits a dynamic snapshot theory (Tononi & Koch, 2015), the experience of succession can only be salvaged within a time-window without mixing it with succession of experiences. However, it raises the question of how IIT can explain the experience of succession across windows without making it synonymous with the succession of experiences. There is no other option left but to fall back on the succession of two snapshots to explain the experience of succession between consecutive windows. Consider a case where there is a beat1-noise-beat2- noise-beat3. We do integrate the beats across two non-consecutive windows (if one may say) and over time (Bregman, 1994, Chapter 3; Koenderink et al., 2012). Such cases prove much harder for a cinematic theory to explain the experience of succession without employing a separate mechanism (probably operating at a different time scale than the windows) that stitches content over windows. Integration of content over non-consecutive windows poses a problem to the identity between the dynamics of content and structure that IIT celebrates. What we hear is a succession of beat1→beat2→beat3, but the succession of windows would imply beat1→noise→beat2→noise→beat3. This creates an inconsistency between how the content unfolds in experience and how the structure does.

## 3.3   Implications

The current workings of IIT entail a flexible timescale over which conscious experiences stabilize, in the range of a few hundred milliseconds (Tononi & Koch, 2015; for a criticism, see Barrett Barrett, 2016). However, this flexibility does not explain how two moments of experience are connected over time. This is problematic given that IIT's conceptual structure postulates isolated moments of experience in

non-overlapping windows. Such a postulation is neither derived from nor explains the phenomenological experience of continuity.

More importantly, IIT does not develop or adhere to existing doctrines in temporal phenomenology. For instance, previous 'phenomenology-first' attempts at explaining consciousness have adopted either a Jamesian or Husserlian view of time (Grush, 2006). In its current proposal, IIT does not strictly fit into existing proposals of time- consciousness or propose one of its own. This leaves the phenomenological foundations of the theory and its conceptual structure incomplete and perhaps incompatible with phenomenological analyses of time. Ideally, the theory needs to explicate its phenomenological grounds with respect to temporal unfolding (Fekete et al., 2018; Kent & Wittmann, 2021); otherwise, it remains incomplete and does not allow us to understand consciousness.

Let's assume IIT would want to adhere to a dynamic snapshot conception of temporality (Tononi & Koch, 2015). Then a more nuanced and detailed analysis of IIT's compatibility with the dynamic snapshot idea is needed (for instance, see Phillips, 2017). Another similar proposal is Herzog, Drissi-Daoudi & Doerig (2020), wherein they propose a discrete retentional framework for visual experiences. Though much ink has been spilled between the proponents of IIT and Herzog et al., being at odds on the spatial organization of a system (Aaronson, 2014; Doerig et al., 2019; Negro, 2020; Tsuchiya et al., 2020), their respective temporal underpinnings seem to be entirely in agreement. That is, the unfolding argument posits that any recurrent feedback system can be 'unfolded' into a purely feedforward system such that their input-output functions match entirely. Several proposed measures of $\Phi$ in IIT would assign different values for these systems despite them having the same input-output functions. On the other hand, it is argued that IIT's causal structure is not arbitrary. Rather by virtue of being phenomenologically identical, it is grounded by a phenomenological structure of experience (Negro, 2020; Tsuchiya et al., 2020). Moreover, IIT is about 'being' and not 'doing', i.e., it is phenomenologically grounded and not a functional theory of consciousness (Albantakis & Tononi, 2021). Despite these proclamations, IIT and Herzog et al. share the same illusionist (phenomo-temporal-antirealist) stance when it comes to temporality.

# 4 Temporal hierarchies and nestedness

## 4.1 Multiple timescales of experience

Multiple timescales have historically been postulated to understand not only different temporal phenomena but also different properties of temporality (Andersen & Grush, 2009; Dorato & Wittmann, 2020; Varela, 1999). An intuitive and oft-cited example shows a difference in timescales for which we are directly aware of changes (in our perceptual experiences) and timescales in which we must make inferences to be aware of changes. Consider, for instance, being aware of the second hand of

a clock moving vs. being aware of the hour hand of the clock moving. Presumably, in both cases, we are aware that a change has occurred; however, in the former, it seems as though we can see the change occurring, while in the latter, the change is inferred.

Over three millennia, different estimates have been postulated for the breadth of time for which we can notice a change directly in our experience. In contemporary phenomenology, these estimates range from a couple of seconds to ~12 seconds. Neuroscientific methods, however, have appropriated this breadth of the 'present moment' to mean either large-scale integration cycles in the brain or the time it takes for us to become conscious of a change (White, 2018). Studies here usually postulate values between 100-300 milliseconds (Hogendoorn, 2022). This range is also precisely where IIT claims consciousness operates (i.e., at ~100 msec scale of windows). However, as one can perhaps more strikingly appreciate when a perceiver becomes conscious of something, it is not the same as the extent of the moment they are perceiving.

To give one last example, before moving ahead, consider listening to a song that has polyrhythms. It could be Mozart's Don Giovanni being played in two different meters, or the constant meter switching in Brahms's Violin Sonata, all of the Indian Carnatic music, or perhaps even the fast double-time swings of a drummer. One of the magical experiences of hearing these music pieces is the nested experience of change in auditory content at two different rhythms, arguably being experienced under the nesting of an extended present moment (Grush, 2006). It is as if what we were listening to in the finest temporal frame was embedded inside a hierarchical temporal content structure. Thus, the notes being played at any instance seem inseparable from their temporal context. A more intuitive way to appreciate the above example is to think of it as a figure- ground separation also in time and not just in space. Therefore, when IIT postulates that conscious content updates at a single timescale of 100ms in non-overlapping windows, it does not seem like this postulate is based on self-evident truths from experience (as posited by multiple phenomenologists like Husserl, Merleau-Ponty, Varela, etc.).

## 4.2   Nestedness within experience

In psychology and cognitive science, the mechanisms responsible for and those that work around consciousness (attention, perception, memory, actions, predictions) have different but consistent time scales. The mechanisms by which we recognize and identify changes, estimate duration intervals, perceive motion, infer causes, and integrate scenes or information from multiple modalities seem to all operate in different but interrelated hierarchical and nested timescales (Montemayor & Wittmann, 2014; Pöppel, 1997; Singhal & Srinivasan, 2021; Varela, 1999). Moreover, the environment in which we act also consists of events happening at multiple nested timescales.

To recognize speech, for instance, an individual simultaneously needs to parse out phonemes, syllables, words, prosody, tone, and pauses. Of course, this also involves localizing sound differentiating pitch and timbre. If we look at the timescales over which these processes stabilize, we would have a range that goes from 1-2 ms (localizing sound) to a couple of seconds (prosody and tone information). While IIT does allow for a flexible time-window of experience, it does so exclusively. That is, they tie experience to one timescale at any given moment of conscious experience. An IIT-derived dummy construction of this experience would perhaps postulate that we go from localizing sounds progressively to understanding the prosody of speech. Essentially, $\Phi$ reaches a maximum at different time scales for different properties of speech, serially. Moreover, by the axiom of exclusion, only one timescale is tied to experience at any given moment. Hence, IIT would not be able to account for multiple timescales and multiple facets of auditory experience (at any moment). However, a theory of consciousness that postulates that each moment is a temporal whole that underlies a nested hierarchy of multiple timescales would not face this problem (see Northoff & Zilio (Northoff & Zilio, 2022) specifically for a comparison with IIT).

Note that an objection to the above argument might be that micro-level temporal properties at a finer grain are subsumed by a macro-level timescale in IIT and thus maintained. To address this objection, let us revisit the example cited in Grush (2006) about the temporal context of a melody. This melody repeats the same five notes in three consecutive bars. However, the notes in the third bar sound distinctively different, even though they are the same notes. Grush (2006) explains this via the 'temporal context' set by the first two bars. The first two bars here persist as retentions during the present moment experience of the third bar. The example here shows how the perceptual content experienced at the moment is phenomenologically constitutive of both the temporal context over a longer time scale (1-2 seconds) and also by the notes themselves being played at a quicker time scale (tens of milliseconds). At the time of hearing the third bar, we hear not only the succession of the individual notes but also the persisting melody over the three bars. It is unclear how the framework of IIT would subsume or embed phenomenological content that evolves over multiple timescales at one temporal grain. Since the snapshots in IIT represent content in isolated windows (dynamic snapshots), embedding multi-timescale phenomenology within this framework would lead to asynchrony or lags in perceiving this melody (Hogendoorn, 2022; White, 2018; White, 2021). This would be remarkably unlike how we hear the melody. If our argument from this example is coherent, it will point to an instance of differences in how IIT's causal structure changes vis-à-vis our experience. This non-identical dynamical structure in IIT and our experience has previously been proposed as a falsification criterion (Negro, 2020). This is yet another way in which IIT's casual structure is not the same as our phenomenological experience.

## 4.3   Implications

In its current formulation, IIT's temporal structure (or lack thereof) leaves out an enormous literature of temporal regularities in and of experience. Evidence of mentality unfolding over multiple timescales is not accommodated in IIT, either from psychology (Pöppel, 1997; White, 2018; Wittmann, 2011), neuroscience (Northoff & Huang, 2017), or even phenomenology (Kent, 2019; Montemayor & Wittmann, 2014; Varela, 1999). Moreover, a single index measure ($\Phi$) is used to capture not only the vividness of the quality of an experience but also its inherent dynamic structure. IIT represents time the same way it is represented on a postal letter via a date. This is a tag that refers to another tag, in this case, a calendar. This is exactly how dynamic snapshot theories argue mental time is represented in a static, non-punctate manner.

A similar debate exists in neuroscience too (Johnston & Nishida, 2001), where it is contested whether neural representations of time are like event tags (punctuate) or dynamic (non- punctuate and extended). Here too, IIT currently falls in the event-time group, where temporal properties of experience are represented separately from the experience themselves (which is itself inconsistent with how IIT conceptualizes structure and content of experience). These implications of ignoring multiscale phenomena in our experience and their mechanisms require serious consideration and fleshing out by proponents of IIT.

From the integration axiom[2], it follows that despite the phenomenal distinctions, and heterogeneous types of content, we still experience a unified whole, irreducible to these distinctions. However, it has to be noted here that the literature points out that different kinds of content unfold at different timescales, possibly nested within each other. Given this, it makes one wonder how isolating a temporal grain at which conscious content updates in time (as in the exclusion axiom) would help achieve this feat of having such a complex texture of experience. We speculate that the exclusion axiom[3] as it stands does not seem to handle multiple time scales.

# 5   Past, present, & future of *time* in IIT

## 5.1   Status quo

Whether an axiomatic approach to study consciousness is an appropriate endeavor is not contested here (for such arguments, refer to Bayne, 2018). We proceed henceforth, assuming that it is, limiting our discussion within the scope of IIT's axioms.

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[2]"Consciousness is unified: each experience is irreducible to non-interdependent, disjoint subsets of phenomenal distinctions." (Tononi, 2015).

[3]"Consciousness is definite, in content and spatio-temporal grain: each experience has the set of phenomenal distinctions it has, neither less (a subset) nor more (a superset), and it flows at the speed it flows, neither faster nor slower." (Tononi, 2015).

Proponents of IIT argue that time needs no axiom of its own based on the criteria of essentiality, according to which an axiom must apply to all experiences (Tononi, 2015). Since there exists an experience of timelessness (Costines et al., 2021; Josipovic & Miskovic, 2020; Metzinger, 2020) in some states of meditation, temporality is not an essential property of consciousness; hence there is no need to consider an axiom for time (see below).

> For example, one can argue that assuming the existence of a subject of the experience, in addition to the experience itself, is unnecessary; that an experience may stay the same without vanishing; that some experiences may seem timeless; that there may be experiences lacking spatial dimensions, as in some dreams, or situatedness (disoriented patients), or figure-ground distinctions (Ganzfeld); that some experiences, such as boredom, may not refer to something in the world; that causality, change, and time may be derived from the existence axiom, and so on. (Tononi, 2015, footnote 3)

> Another notable property of consciousness is that experience changes all the time. However, since "timeless" experiences can occur, at least "for a short time", it is arguable whether change should constitute an axiom/postulate. (Tononi, 2015, footnote 12)

Timelessness and experience of other such states, however, are not unambiguously posited in the current times. Their description and thus conceptualization are still underway (Costines et al., 2021; Metzinger, 2020; Srinivasan, 2020; Windt, 2015; Woods et al., 2021). With our scientific understanding of such minimally phenomenal experiences (MPE) still evolving and rudimentary, it may be too early to entirely rule out an axiom for time based on an exceptional case. Even if such a state has to be considered seriously by IIT in its current formulation, we argue that it would imply complications for its existing axioms as well. The phenomenological descriptions that accompany such states are not only that such an experience is timeless (Josipovic & Miskovic, 2020; Metzinger, 2020; Srinivasan, 2020) but also perspective-less, composition-less, non-flowing, non-specific, contentless (where there is nothing to be integrated or differentiated), etc. These descriptions would thus entail invalidation of IIT's existing axioms. The properties of experience captured by IIT's axioms would also fail to be universal and fail the essentiality criterion test. MPEs, in general, pose a problem for many theories of consciousness (Srinivasan, 2020).

## 5.2   All axioms have "now"

Temporality and moments of 'now' are so inexorably linked to consciousness that an attempt to detail the properties of experiences necessitates an anchor of 'now'. This is a feature either explicitly or implicitly in all of IIT's five axioms. One can

appreciate this by looking closely at the axioms themselves and how the word 'now' is used in defining those axioms themselves.

The existence axiom explicitly details that 'consciousness exists here and now'. The second axiom of composition states that 'within one experience I may distinguish' several different components. Here again, since an experience cannot exist without having a temporal extent, detailing something happening within an experience is again impossible without carving out a 'now'. The third axiom of IIT individuates each experience from another; by virtue of this, an experience is said to be informative. However, the specificity and differentiated-ness of one's experience can only be via and inside a 'now'. The fourth axiom (integration) illustrates how multiple phenomenal distinctions co-exist as a unified whole, and experience is irreducible to these individual distinctions. This is true not only in space (inside a visual scene) but also in time (inside a moment of now). The final axiom captures the idea that our experiences seem to have a specific spatio-temporal grain and flow at a particular speed, not faster or slower. Interpreted from the view of temporal phenomenology, this axiom could be read as saying that our experiences have (1) a certain temporal breadth and (2) speed at which they change. This is just another way to describe a 'now' moment, albeit the breadth of this now speculated to be at ~100 milliseconds is not derived from any feature of experience, which is self-evident.

A more intuitive way to understand what we mean by arguing that all of IIT's axioms necessitate an anchor of a 'now', is to ask: *When?*. IIT posits that experiences are real, informative, compositional, integrated, and exclusive, but when?. 'Now' may seem like a trivial answer to this question. Our point of contention is, however, that the now is a temporal carving of experience via phenomenology. It is a present-like moment with an extent (James, 1890; Kelly, 2005; Kent & Wittmann, 2021). A dialectic contradiction where aspects of just-past and about-to-occur futures co-exist within a temporal whole (Dainton, 2010). It is one possible phenomenon that differentiates consciousness from unconsciousness (Blackmore, 2012). Without understanding the temporal properties of this phenomenological and psychological "now" and the flow of conscious experience, we cannot understand the structure of experience. This conclusion has been reached multiple times in the last few hundred years (Andersen & Grush, 2009; Dainton, 2010; Whitrow, 1980).

## 5.3   Proposed axiom of time

We concur with many previous proposals which argue that the study of consciousness can be constrained and meaningfully improved through phenomenology (Van Gelder, 1999; Varela, 1999). As such, we appreciate the phenomenologically driven stance of IIT. Our contention here has been only that IITs phenomenological analysis is incomplete. We propose a way to address at least one shortcoming in the

phenomenological foundations of IIT. We think that there is a need to propose a temporality axiom.

Previously, an axiom for time was proposed by Hunt (2016) addressing the shortcomings of IIT's axioms in accommodating temporal passage of experience: "Along with the undeniable reality of consciousness itself, the passage of time from moment to moment of our consciousness is known to each of us as certainly as anything else is known." The corresponding postulate supposes a strong process-time philosophy, which assumes that there is temporal passage in the external world and our experience is a mapping onto it. Further in this section, we propose our own axiom and contrast it with Hunt's.

Our proposed axiom comes from a first-person phenomenology approach. It would enable IIT, and future theories that would be of similar nature, to fill the gaps pointed out by our critique. It takes temporality in our experience as primary and is based on a naive account, wherein we "experience" only in terms of a temporal whole. Moreover, it makes explicit that our experience has a temporal extent and a direction.

> *Time Axiom: Consciousness is such that experience occurs to us as a temporal whole; i.e., experience always has an extension, is continuous, and has an inherent direction that is asymmetric.*

If this axiom is tenable, the conceptual framework in IIT would need to be altered to accommodate temporal phenomenology. It also might be necessary to alter other axioms of IIT to ensure the set is complete and independent, which we do not attempt to do in this paper.

We are presently neutral to whether an axiomatic approach to consciousness is the way to develop theories of consciousness. Our aim here is only to add an important but missing piece given the basic approach of IIT. An objection to this axiom might be exceptional experiences (MPE, for instance), which are reported to be timeless (Tononi, 2015). We have mentioned earlier in the paper how these experiences are problematic for other existing axioms of IIT as well. Perhaps such experiences may need to be understood better before they are used as justifications for excluding axioms. Perhaps that may even require different ontological commitments. Moreover, it is possible that MPEs may lack many temporal properties but not all temporal properties[4]. For instance, these experiences may still have the temporal property of persistence, endurance, or extent[5]. These claims, of course, need to be formally investigated and remain only speculative for now. Our larger

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[4]Vogel et al. (2020) proposed a temporal framework consisting of two Time-Layers (micro and macro) and two Time-Formats (structure and flow) to distinguish how the implicit temporal properties of experience form a basis for the explicit ones. Within this theory, it is possible for only selective temporal properties to be distorted.

[5]For an example of this, see Windt (2015) for a discussion on how MPEs may involve losing a reference point in time where succession of events is lost. But the temporal extent of a phenomenological now is maintained.

aim here is to point out that a phenomenology-first theory like IIT cannot ignore temporality in and of experience.

Our proposal differs from Hunt's (2016) proposal in significant ways. One, we do not prescribe to a process-time philosophy or make ontological claims about time passage in proposing our axiom. Our approach to time consciousness is via a first-person phenomenological perspective. Two, we detail how passage of time is not the only temporal property of importance and we argue in this section how absence of passage (in the case of timelessness) does not have to entail an absence of temporality. Since Hunt's proposal only includes one property of time (i.e.) passage, it does not capture other temporal properties. Third, his proposal does not consider the nested hierarchical nature of temporal consciousness. Fourth, the axiom as proposed by Hunt (2016) is explicitly formulated in epistemological terms ("known to each of us as certainly as anything else is known") potentially raising further questions especially given the cinematic conception of IIT. The aim of Hunt's approach was to rewrite IIT's exclusion axiom while allowing it to account for temporal passage.

Our objective in this paper is not to rewrite a specific axiom of IIT. However, the current formulation of IIT is based on a cinematic conception of temporality where our experiences only 'seem' continuous (see section 3.). Thus, the axioms need to be modified if they have to come from the truth of the first-person experience. How the axioms need to be rewritten or modified based on our proposal is a matter of future debate and is contingent on accepting that currently IIT is unconstrained by temporal phenomena.

# 6   Implications & conclusion

In its current formulation of IIT, we have comprehensively described how despite claiming to be a phenomenology-first theory, IIT takes neither phenomenology nor its literature seriously. As a theory that champions the study of the intrinsic structure of consciousness, not just its extrinsic functions (Ellia et al., 2021), proponents of IIT ignore and misconstrue the one property that phenomenologists, psychologists, and neuroscientists have been spilling ink on for centuries- temporality. It is important in the context of IIT, given it is also the only property conscious experience that is common between its structure and content and is argued to be one of the three candidates for a minimal unifying model of consciousness (MUM) (Wiese, 2020). Upon close inspection, as we did, one can find the glaring inconsistencies that arise when one sits down to chart out temporal properties of experience within IIT's constraints and axioms.

With the inconsistencies we point out and the axiom we have proposed to address them, we believe that at least one of four possible actions must be chosen by the proponents of IIT. Two of these entail IIT either giving up its phenomenology-first and/or identity-based groundings, at least when it comes to experienced temporality. A third option is for IIT to make accommodations for a time axiom and

revisit the workings of its cause-effect repertoire in this light. Of course, our criticisms could be entirely misplaced. Showing we are wrong and time/temporality is not needed for explaining consciousness could be a fourth possible action taken by proponents of IIT.

Tononi, Massimini, Boly, & Koch (2016) end their paper by saying, "Time will tell whether this account (IIT) is anywhere near the mark". They perhaps meant that the correctness of IIT will only be established in the future as more work is done on it. However, in this paper, we have argued that (phenomenological) 'time' is already telling us that IIT is not anywhere near the mark. In this critique, we have argued that IIT, as proposed, does not address temporality explicitly to constrain its conceptual structure. Specific temporal properties of experience are ignored or missing presently in the theory. Further, the implicit suggestion of a discrete framework undermines several commitments made within the theory and falls short of explaining various temporal phenomena. Thus, in the present form, there is neither a phenomenology-first stance nor a phenomenology-identity for time in the framework of IIT. To partly rectify this, we have proposed here a new axiom for time. To accommodate this, we feel that IIT needs significant revision.

# 7    Acknowledgements

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