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Commentary

Modern Monads: Leibniz, Continuity, and the Stream of Consciousness

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What is a perceiving 'me' or 'soul' and does it endure, perhaps for eternity, or is it merely one of a sequence of evanescent events? Conscious perception poses several puzzles in relation to subject identity and continuity that Leibniz paid close attention to. Re-applying Leibniz's principles in a modern context suggests two conclusions. Firstly, his search for fundamental indivisible (monadic) perceiving dynamic units looks as motivated as ever. Secondly, modern physics may suggest ways to mitigate the temporal paradox raised for Leibniz by Russell, in which events of experience may be both distinct and part of a continuum. Recent condensed matter physics provides a hierarchy in indivisible dynamic units that invites a more subtle application of Leibniz's ideas on continuity and divisibility. Our experience as a 'string of mental pearls' may be peculiar to certain types of fundamental dynamic unit with a 'constant internal principle of change' but variable energy content, typified by collective modes of excitation in condensed matter. In simple terms, a local domain of the electromagnetic field may 'inform' a collective mode (such as an acoustic mode) both by bringing it into existence and, in addition, through ongoing variation, updating the mode about changing events to which the mode can respond with shifts in energy content. These shifts will divide the mode into individual indivisible excitations - perhaps the best candidates for individual events of experience. Leibniz's monadic analysis may not escape intact, but his guiding principles may.

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> *"Indeed, as I have worked through Leibniz's system, I have seen some ways in which I might depart from what he has presented ... but this benefit of vision comes only through the hard work of seeing things through his eyes for a bit." Larry Jorgensen, 2019.*

Introduction

The most obvious gap in modern science is an account of what it is that enjoys rose-red, the warmth of the sun or peppermint. Is it a thing, a system of things, a process, or just a window through which a universal consciousness peeks for a brief time? A challenge to any theory of the nature of perceiving subjects or 'souls', whether in 1700 or in the context of modern biology, is what would constitute something that could be the 'same thing' over time and yet be subject to constant change.

Every conscious experience appears to be at a point in time - even if sense of movement might seem to need more than one point and William James's (1893) 'specious present' can present a whole musical phrase. We do not, however, know whether to regard experience as a 'string of (discrete) pearls' - maybe as for computing automata, like those built by Leibniz, (Jones, 2018) moving from one state to another - or as a continuum, like the flow of branches through a brushwood shredder. And either way, we have no idea what determines the temporal width of 'now', either in terms of brain signals representing outside world or events being represented, because we do not know the *identities of the interacting units* or elements involved. Nor do we know in what sense, if any, these identities endure through life.

Leibniz (e.g., 1678; 1686; 1693; 1695; 1714; 1765) spent a lot of time on continuity, individuality, points, sequence and divisibility in space and time. Are his deliberations relevant today? I think Jorgensen (above) gets it right. In *Critical Exposition of the Philosophy of Leibniz* Russell (1900) argues that, however powerful the logic, Leibniz's analysis fails through contradiction, particularly with regard to time. Russell cannot see that a perceiving soul can (as Leibniz claims) both exist as an indivisible unit, encompassing all events it will ever encounter, and yet move from one event to another as a series of perceptions. Leibniz's work is consigned to the status of idealist fantasy. A century later, however, Russell's analysis has itself been challenged (see Arthur, 2018; Jorgensen, 2019). I shall argue below that, even if Russell has a point, his analysis is too quick and misses the opportunity to see how the apparent contradiction might lead to a deeper analysis.

Leibniz's principles can sound dogmatic and abstract but in intended context are often truisms that provide common-sense insight into contradictions in our intuitive sense of reality. Many of his ideas re-surface in modern physics, even if practical implications are not quite as proposed. Difficulties claimed by commentators often involve ambiguous words, like 'parts' or 'continuity', taken beyond intended context. There remain times when it is hard to see how Leibniz's schema works, but that may not mean he was wrong. It is not as if we have a better solution to the nature of souls.

For Leibniz (1714), perceiving souls are not, as they were for Descartes (1649), in addition to matter. They are, as well as being subjects, the basic constituents that explain the behaviour of material things. Familiar objects appear as 'phenomena' – concealing a reality of perceiving dynamic units, or monads. As Jorgensen says, the picture is a naturalistic one, explicitly relating mentality to physical dynamics: something recent biology has fought shy of. For Leibniz (1765, pp236-7) 'real physical identity' is the level of soul; his metaphysics is the fundamental level of physics, not something other. It is inferred from contradictions in accounts of physics, not 'arbitrary', as Russell would have it. There is good reason to look for applications of Leibniz's proposals in empirically established physics today.

The aim of the following discussion is to explore how Leibniz's framework might help us work out what conscious perceiving subjects could be within modern biophysics. Following a general overview, the focus will be on the potential paradox of temporal indivisibility and how possible solutions might shed light on where we should be looking.

A Glimpse of a Model?

Leibniz never offers a specific domain of operation for a human subject like Descartes's pineal. There is, nevertheless, one place where Leibniz (1765) hints at the dynamic structure he prefers, even if presented more as metaphor than model. His imaginary dialogue with Locke, *New Essays on Human Understanding*, provides a brief description of how he views 'perceiving 'souls'.

The passage is part of a wide-ranging discussion, sandwiched between a comment on madmen and a taxonomy of 'complex ideas', given in response to Locke's (1689) metaphor for mind: a darkened room with openings through which images could enter and remain, to be 'found on occasion'. Leibniz adds:

> *To increase the resemblance we should have to postulate that there is a screen in this dark room to receive the [sensible] species, and that it is not uniform but is diversified by folds representing items of innate knowledge; and, what is more, that this screen or membrane, being under tension, has a kind of elasticity or active force, and indeed that it acts (or reacts) in ways which are adapted both to past folds and to new ones coming from impressions of the species. This action would consist in certain vibrations or oscillations, like those we see when a cord under tension is plucked and gives off something of a musical sound. For not only do we receive images and traces in the brain, but we form new ones from them when we bring 'complex ideas' to mind; and so the screen which represents our brain must be active and elastic. This analogy would explain reasonably well what goes on in the brain. As for the soul, which is a simple substance or 'monad': without being extended it represents these various extended masses and has perception of them. (Translation by Jonathan Bennett.)*

The aim is to counter Locke's model of mind as a 'blank slate' or empty closet where pictures can be dumped. It is easy to see why Leibniz suggests a receiving device, with a prearranged, but modifiable, structure, allowing images to be interpreted in terms of innate concepts (perhaps identity, animacy etc.) and memories. Leibniz suggests his model as an analogy but that may hide more concrete unspoken thoughts. The conscious subject or soul is treated as something 'non-extended' that nevertheless perceives or monitors interactions between incoming signals and structures within a clearly defined domain. The proposal of a vibrating membrane is intriguingly specific. A non-extended 'soul' might sound alien to biophysics but modern physics has dynamic units with little resemblance to traditional concepts of matter. If such units could be perceiving subjects, crucial criteria for candidates will be factors governing spatial and temporal domains and boundaries. Russell was probably right to suggest time is the more critical issue.

Modern Monads: Field Excitations

Leibniz's (1714) monad was defined as a single indivisible unit of action or force, conserving a quantity we now equate to energy, that in itself had no material extension but could associate with aggregates of other monads appearing as extended material bodies. In effect, modern physics gives us the same.

The modern monad equivalents are known as field excitations, or modes of excitation, once called 'particles', or in some cases 'quasiparticles'. (All of these terms are misleading. In what follows I will use the simple term 'mode' to denote a type of excitation and 'excitation' to denote a token instance.) In effect they are units of change within universal fields, each mode with an unchanging

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mathematical pattern of 'drive' (disposition to change) arising in the context of (in harmony with) a gradient or asymmetry in one or more universal fields. As for Leibniz's (1714, §3) monads, they are unenvisageable in familiar terms we use for aggregate phenomena like 'shape', 'size' or 'motion'. In crude intuitive terms, whenever the universe's fields are out of kilter (bear an asymmetry) an excitation can arise in response – like a lightning bolt rebalancing unequal atmospheric charge.

This may sound obscure but many modes are familiar categories: photons, electron orbitals, quarks etc.. All their properties, like mass and charge, boil down to powers to express or engage forces (passive and active). The property of 'spin' explains the mutual domain exclusion of Fermi (electron) modes that is the basis of the aggregate 'extension' of matter identified by Descartes (1641).

Of particular relevance to Leibniz's suggested model for a soul is that in addition to these subatomic modes, field theory recognises modes arising with asymmetries at all scales. Vitiello (2001) has suggested that in an ordered biological structure, like brain, we can expect long-range modes to set up, based, in part, on what is known as Nambu-Goldstone theorem. The background is technical but all we need to know here is that everyday phenomena like sound waves and electrical conduction in metals involve modes with domains far larger than atoms – including the Albert Hall. (Excitations can be classified into modes broadly or narrowly. Hopefully, the chosen usage here will be clear – focusing on these larger scale excitations.)

Leibniz (1765) says of a soul associated with a brain (in Bennett's translation): *without being extended it represents these various extended masses and has perception of them.* It is not certain whether he sees a soul as relating to one vibrating membrane or many, although he only mentions one. I will return to the issue of multiplicity later but want to keep the discussion general here. The key point is that modern field theory explicitly provides 'action units' in the form of modes that inhabit ordered structures like vibrating membranes, most obviously the acoustic or phononic modes of sound. Vitiello (2001) has been interested in modes that involve oscillations in populations of neurons. My own analysis has focused on individual neuron structure (Edwards and Somov, 2023). Modes within ordered components of individual neurons would be easier to fit with modern neuroscience but raise the need for *monadic multiplicity* in brains. Leibniz envisages (infinite) monadic multiplicity but with a dominant monad that no longer looks plausible. I shall return to this issue later.

In the simplest of terms, it would be nice to have a basis for some non-extended action or spirit units compatible with biology that would fit with the fact that we wake up in the morning with no measurable increase in brain size or weight, just a disposition to start the day's activities in the context of perception. Mental life may seem far too rich to fit into any single biophysical unit, but we know brain structures to be complex.

What about conscious systems? There has been a fashion for linking consciousness to complex, perhaps self-organising, systems. No doubt, as Leibniz (1714, §75-77) implies, complex nervous systems can provide perceiving subjects with highly collated information about the world. Complex systems and subjects that respond to rich meanings would synergise well. However, a system of interacting dynamic parts cannot provide the single *indivisible point of view* that motivated Leibniz's concept of simple substance, and which I believe remains cogent. It cannot provide a single indivisible relation to environment that could be an event of experience. (See Edwards and Somov (2023) for a detailed analysis in a brain context.) An indivisible point of view may involve a distributed spatiotemporal domain but not functional parts, especially sequential or temporal parts. Each part would have a different relation to world, including other elements. Moreover, to be non-arbitrarily defined the system would need to be closed (with a Markov 'blanket') and nervous systems are about as open as you can get, in both informational and thermodynamic terms. In contrast, modes of excitation can relate from such a distributed domain to rich field patterns, in a unified way that avoids any need for further 'combination' or 'binding' of aggregates of events.

Leibniz's (1714) account of souls was influenced by piety and many might want to leave behind his claim that a soul is immortal. He says that for any 'natural automaton' with the perfection of function found in naturally occurring (rather than man-made) objects, there will be a dominant dynamic unit or monad whose active nature is reflected in that function (Leibniz, 1714 §64). All real unities consist of a unit of drive matched to a body. This fits particularly well with the longer-range modes of condensed matter. The problem comes when Leibniz (1714, §75-77) wants the same monad to have pre-existed as a spermatic animalcule before the human body is formed and to continue within a speck of dust after death. Modern physics probably holds to Leibniz's principles better than he; modern units of drive *must* 'reflect' the field gradients of their domains. An s orbital of an iron atom cannot conduct electricity. (And there is no tenant 'electron A' to carry over identity to a conducting valency orbital.) An acoustic mode of a violin string cannot occupy Big Ben. Leibniz had so few clues to the fundamental level he might be forgiven for stretching his model, but if modern biology is to look for dynamic individuals that fully fit his Principles, it is going to want units matched to condensed matter structure.

In summary, with a major proviso about immortality and perdurance through bodily transformations, Leibniz's principles seem to translate rather well to a modern context. As he deduced, fundamental dynamic units are units of constant 'drive' reflecting stable local asymmetries. A real individual exists in this form in a domain of space and time. There is, therefore, agreement for the third-person account of a unit but what about perception and experience and associated questions of continuity and divisibility?

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Continuity, Divisibility and Identity

The backbone of Leibniz's (1686; 1694; 1695; 1710) theory is that in dynamic terms the universe is both continuous and constituted by discrete entities. The key to resolving this paradox is that the nature of *fundamental* entities is not space-occupying extension, but force (drive or entelechy). This frees dynamics from the prison of Descartes's extension in which, moving through space, we encounter one thing suddenly stopping as another starts. Modern field theory similarly paints the universe as a continuous pattern constituted by the totality of individual 'quantum' steps of action - with no precise edges.

Although time is more interesting, Leibniz's case for continuity is most easily introduced in the context of space. Rejection of Descartes's concept of matter as extension allows Leibniz (1695, §46-47) to postulate a Law of Continuity, underpinned by the logical argument that differences across space or time in a physical description cannot have infinite rates of change (gradients).

Leibniz argues that it is incoherent to try to explain a dynamic difference, say across space, in terms of an infinite *gradient*, particularly if the difference itself is finite. Such a gradient would need to be due to some infinite force, yet with finite effect. As Jorgensen (2019) discusses, this argument follows from Leibniz's Principle of Equipollence - cause and effect must be matched in terms of a quantity of 'force' or causal power - now recognised as conservation of energy (see e.g. Leibniz, 1695, §12-20).

The practical significance is that there cannot be, at a fundamental level, hard edges to things. For Descartes, material elements 'owned' a space, preventing other matter from entering. Work on elasticity and gravity showed this was wrong; profiles of dynamic properties across space *tail off*, as in Hooke's Law or the inverse square law.

Leibniz's Principles also mean that material atoms cannot be infinitesimal points; that would imply not just an infinite gradient but opposite gradients at the same place! Leibniz's law gives the *a priori* case for Heisenberg's Indeterminacy Principle. Spatial location must be 'vague' (Gerhardt, 1890; Arthur, 2018, p284). Profiles of dynamic properties must tail off – in line with wave packets in modern physics. The domain of interaction of an s orbital electron mode has a single hump profile, a conducting valency mode in metal more an extended blancmange, but, as Leibniz predicts, the domains covered by their wave equations notionally extend throughout the universe if only in a trivial 'confused' way.

How would this apply to vibrating membranous 'bodies' inhabited by a global action mode forming a 'soul'? For Leibniz the body is an aggregate of monads. Its apparent integrity will be due to myriad lesser monads with overlapping non-trivial domains of action operating in close harmony – perhaps in modern terms 'entangled'. The soul is then a higher monad that inherits the non-trivial aggregate domain as a single distributed action unit, again with a trivial or confused relation to everywhere else. This compares well with the current idea of a distributed acoustic/phonon mode with no unique location, being the *global* action of, for instance, a violin string.

Of crucial importance is that Leibniz's continuity is not about individual things being joined together or fused. He denies anything has connected parts in that sense – mereology is abandoned. He also claims that dynamic individuals come into and go out of existence in their entirety. Identity at the fundamental level is completely discontinuous – such that one monadic unit is quite distinct from another and is either all there or not at all. Identities come in monadic or quantum jumps.

Divisibility in Time

As Arthur (2018, p254-289) emphasises, Leibniz's (1710, p393; 1714, §11-14) concept of fundamental individual is *diachronic:* an unchanging drive that endures. Being this same dynamic entity over time is being an individual rather than a heap. It is also this continuity of a unity over time that gave Russell trouble.

Continuity in time immediately gets complicated. The law of continuity requires that the time domain of interaction of a dynamic unit also spreads out indefinitely – arguably, for Leibniz (1714, §6, §74-77), back to a time of Creation. It also seems to spread forward to the Day of Judgment. This seems problematic for both our intuitive concept of causation and the law of locality, limited by the velocity of light. However, a similar problem lurks in modern physics. A formal analysis is beyond the scope here, but some further discussion is included below. Fortunately, the issue is largely tangential to questions about perceiving subjects.

Leibniz's view of time is also bound up with his approach to determinism. Modern discussions of determinism focus on whether rules of how one event follows others are rigid (deterministic) or have leeway. The former is equated with the future being fixed and the latter with it being 'not yet determined'. Leibniz (1686, §13) sees the options differently. He claims the *rules* (reasons) cannot be rigid. They must allow a variety of sequences of events. Nevertheless, *this* universe has only one possible future, belonging to it from the outset. As is hard to deny, whatever the future of our universe is going to be it will be what it is going to be. Only in another universe could the future be different.

Leibniz is making use of his idea that any *identified* thing about which we can form true propositions must be considered as a 'complete notion' (Leibniz, 1686, §8). In a sense, he is making claims about entities from a position outside time. This leads to the surprising claim that the entire future of a monad or universe is entailed within it from the outset. That might simply be saying 'qué será - *será*', but he is implying more: if an entity genuinely cannot be divided into dynamic parts in time or space its entirety must be determined from the outset.

However debatable this might seem it turns out to apply literally to indivisible things in modern physics. *That* photon, being nothing more than a unit of *connecting* change, does not begin to exist until its whole life history does. What seems like Leibniz's rarefied logic becomes an empirical fact for something that truly has no dynamic subcomponents.

Moreover, the fact that *that* photon's identity is inseparable from events involved in how it is finally 'measured', and apparently on for ever, suggests to some that physics requires a 'timeless' block universe that makes Leibniz's stance look prescient. But things are subtle. As indicated above, in the relation of *universe-to-unit*, both for Leibniz and modern physics, the existence of the unit is notionally informed by, or reflects, all spacetime – back and forward. In contrast, the relation of *unit-to-universe* consists of action in a finite domain constrained by locality. Equipollence applies, but with asymmetry of domains of cause and effect. Individual excitations have a relation to all time and all places in their origin but a defined domain in their effects.

The problem is that for Leibniz's concept of an immortal human soul going through various perceptions and actions an inconsistency arises. *Qué será, será* applies in the broad context of this universe being the one it is and Aristotle the man he was. But unlike a photon a human soul seems dynamically divisible in that we can observe repeated interactions with world as time goes along. Leibniz does not allow one individual to change into another. Yet he does claim that a monad exhibits unchanging or constant change. If that were simply a change in what it relates to that might seem OK, but Leibniz emphasises the dynamic, or relational, nature of the monad's essence. Russell, at least, was not convinced.

Another issue is if, or how, we can 'divide' time. Leibniz (1714, §14) describes monads as moving from one 'passing state' to another. He also appears to see dynamic relations as fundamentally rational, implying that going from state to state is analogous to his automata performing logical tasks. These sound like temporal parts. Does an individual dynamic unit have one eternal interaction with world or is it divided into a series, each with a profile with tails reaching back and forth? Or is there a third solution?

A further question is if Leibniz (1686) uses the existence of separate points of view as his primary evidence for the existence of distinct dynamic individuals, why do different experiences occurring in a sequence not count as distinct units?

There are puzzles here. If the monad is enduring but interactions of perception are passing states, how does it hitch-hike from one to the next? It seems either there are boundaries between each 'pearl' of perception or not, and Leibniz wants both. If we want to find a monadic dynamic unit that can fit within biological structure and be a perceiving 'soul' we need a principled way to resolve the paradox. Perhaps against Leibniz's better judgment, we want an enduring mode that can nonetheless have 'passing states'.

The Temporal Paradox

The key temporal problem posed by Leibniz's idea of a dynamically indivisible unit associated with a living body is that if it is indivisible in the uncompromising way a photon is, it is hard to see why it does not just have one experience reflecting its entire spacetime domain. What would divide the relation of the dynamic unit to the world into discrete percepts, and what would determine their temporal width?

The question might appear empty if we do not think photons perceive. However, we think animal subjects perceive because we see behaviour indicating something within is informed or influenced by environment. In operational terms we have the same for a photon; measurements indicate it has arisen from influences or necessities provided by environment. It behaves as if informed by a lens or a pair of slits, or, in quantum theoretic terms by field patterns integrated over all possible notional paths. Those who see Leibniz as idealist may argue that dynamic units of modern physics are too 'physical' to be monads. But, surely, this is back to front. For Leibniz, it is the everyday 'physical', the appearances of objects he calls phenomena, that is just ideation – as neuroscience confirms. As Arthur (2018) points out, if by 'physical reality' we mean the 'atoms of nature' *underneath*, for Leibniz (1714) it is monads.

Following this operational account of an indivisible unit being informed, it is interesting to see why a photon is considered indivisible. The only information the photon can give up or 'report' is, using Feynman's (1990) analysis, dependent on all notional 'paths' for the photon from genesis to annihilation. A photon from a star gives up information about a vast spacetime domain, never a 'time-slice' subdomain. A photon presents itself as having one indivisible relation to other.

This 'indivisibility of a quantum system' is regarded as a universal rule for modern treatment of fundamental dynamic units. If an excitation of a field, whether a photon, an electron orbital or free electron mode, interacts with its environment and thereby makes a measurement possible, it ceases to be that excitation and mass, charge, energy etc. are subsumed into some new excitation. On this basis it might seem that all fundamental units could only have one indivisible relation of perception to world that could contribute to history and be known about.

There is, however, a complication. The dynamic units mentioned are simple excitations that do not change energy content over time. In condensed matter modes of excitation can be collective, reflecting patterns based on large numbers of notional energy subunits. Vibrational modes based on phonons are the most familiar. Collective modes of excited electrons are another. Modes of this sort will be informed by a field of electromagnetic potentials through coupling such as piezoelectricity (see Edwards, 2020). Suggestions are speculative but I believe there are plausible options based on semi-crystalline cell components such as cytoskeleton. I make use of acoustic/elastic modes (sound waves) in following discussion because they are familiar. There are

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good reasons to consider electron exciton modes of interest (Craddock et al., 2017) but they are complicated.

For collective modes, the dynamic pattern may remain stable over extended periods while amplitude varies as notional energy subunits come and go. The mode of vibration of a violin string (open position) remains constant but its amplitude varies as it is played. Unlike the photon the string can tell us about events in the immediate past rather than ever since tuning up. Are such collective units true units if they can acquire or discard notional energy subunits? Leibniz might say no. For him the individual substance always has the same internal 'principle of change', which might include constant energetic drive or, in his terms, force (Leibniz, 1678).

Another potential objection to bringing in collective modes as true individuals is that they are often seen as 'classical' rather than quantised units. Yet they have legitimate quantum-level descriptors including a quantum number for notional amplitude units, (e.g., individual phonons). Remarkably, this number must be an integer yet there may be no fact of the matter what it is, as it is subject to Heisenberg's Principle. An enduring mode seems more real than any 'parts'. Moreover, their intrinsic existence as dynamic individuals is required, quite apart from quantum theory, by statistical thermodynamics, which identifies them as deserving allocation of a share of energy.

I am aware of little discussion of how these matters are best resolved in the context of identifying individual units that could be perceiving subjects. My own view is that Leibniz's concept of fundamental dynamic units, associated with condensed matter 'bodies', capable of undergoing sequential relations of perception to world is plausible within modern physics. If the dominant monad for an ordered biological structure belongs to a form of collective mode, we can expect it to last the lifetime of the structure but respond sequentially to environmental patterns. Those responses could be in the form of elastic impulses or impedance changes.

I have come to the view that, in practice, Leibniz's conception of the monad and its body needs an extra layer. In a sense, Russell was right to identify a contradiction. That layer can be supplied by a distinction between a type or mode of excitation and an individual token excitation. Types of excitation are familiar as ensembles in experimental set ups. For collective modes it may be be useful to consider an ordered structure to be associated with an enduring *mode* of excitation consisting of a large number of sequential *individual* excitations, each with different energy content. A somewhat similar case is a cloud chamber where a line of droplets appears to display the 'path of a free electron' but in fact shows the chain of connections made by a series of individual excitations of the electron field, each with certain identical parameters (charge, spin) but slightly less energy.

In this analysis individual indivisible perceiving monads would be each of a string of evanescent excitations within a collective mode. One could argue that for an acoustic-type mode the individuals could be individual phonon 'quanta'. However, this is problematic because single quantal energy steps are regarded as notional, with, as mentioned, no precise fact of the matter how many there are. A more robust solution would be that whenever there is an actual change in energy quanta content, from some whole number n1 to another whole number n2, however uncertain we may be about what these numbers are, that produces a measurable influence on the environment (maybe an electric current), a new individual excitation is created. This is consistent with the quantum theoretic dogma that an actual excitation exists to the extent that its effects are in principle measurable.

I suggest a pragmatic analysis, that puts aside Leibniz's quest for immortality but follows his Principles. I think it plausible that brain tissue contains dynamic units in the form of *modes of excitation* that reflect patterns of local structural order and endure, perhaps for years. They can relate to environment in two ways. One is to reflect a stable asymmetry. The other is to reflect fluctuating field patterns within those asymmetries and respond by shifting energy content. Each new response can be considered a 'choice'. This unit might be considered a 'monadic mode' of the local structure. The true indivisibles would, however, be a chain of individual monadic excitations. The mode might be considered to perceive and choose over time but perhaps in a vicarious way that would deny it the status of individual monad. The individual excitations would be the true perceiving souls.

This hybrid analysis might neatly explain why our perceptions seem to belong to an enduring entity and yet are fleeting and irretrievable other than through shadowy replay in memory. This view may sound like Locke (1689), but the justification comes via Leibniz.

A final dynamic aspect I can only touch on briefly is Leibniz's insight into end-directedness (see Edwards, 2016). A dynamic unit in modern physics entails an actual, achieved, end, because its identity includes its terminus. Leibniz (1714, §15) conflates this with directedness to an *envisaged* end, *not always fully achieved* – i.e., purpose. For a photon 'partial achievement' makes no sense, but for a collective mode, with variable amplitude, it might. Each individual excitation must achieve the end it reaches but over a longer period the mode might be seen as having a vicarious 'purpose' that may or may not quite be realised Again, this may fit with the rather odd way our intuitive sense of purpose fits with the end-directedness of modern physics. We know that our perceptions are indirect and that the way our brains construct representations of world dynamics is not always self-consistent.

Other ways to explain the extent of the present?

Leibniz (1710) insists that all perception requires a finite length of time (see Arthur, 2018, p273). His argument is subtle but what seems firm ground is that to give anything real identity through dynamic role it must have duration. What is up for debate is whether a perceiving subject lasts just one percept, to be replaced by another, or endures from percept to

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percept as Leibniz claims. As Arthur (2018, p84) says, Leibniz (1710; 1714) defines a substance as having diachronic unity across many perceptions. This needs careful thought. It brings into focus the question of what could determine the *temporal width* of percept. The proposal above is that Leibniz was at least in part wrong and that temporal width is determined by individual evanescent excitations. Leaving that to one side for a moment, how might we identify a temporal width consistent with perception by an enduring mode?

A possible approach is to think of the interaction with environment as more like the continuous action of a brushwood shredder through which branches flow continuously. The content at any time t1 is distinct from that at any other time t2, even if the process has no discrete divisions. In this context what would determine the temporal width of interaction? The obvious option in the context of quantum theory is that the perceiving mode can be seen as a Gaussian wave packet constantly recycling through the ordered structure it inhabits. If the temporal domain of the packet covers several cycles through the structure it will appear as a constant standing wave.

Thus, although it might seem that multiple distinct experiences must imply temporal divisibility and hence discontinuities, there might be an alternative. If experience covers a domain in the form of a wave packet, the domain of interaction can progress in real time without boundaries. If the wave packet is passing through or inhabiting a medium that changes in fine detail it is possible to distinguish a series of distinct states with different contents despite forming a continuum.

The problem is that this is a classical analysis, only valid for a mode, as in the notional travelling waves in a violin string played continuously but with varying intensity. At a fundamental quantum level it does not work. The classical account is for an aggregate system and so cannot relate to our sense of the indivisibility of events of experience. At the quantum level there is no real 'progressing wave packet'. Quantum physics is often described in such terms but interpretation in terms of a wave 'moving in time' cannot work because an excitation is an indivisible causal connection that depends on a single integral over both space and time. There is no 'before' or 'after' within an excitation. As much as it is 'in all places at once' it must 'at all times at once'.

For an individual excitation, between shifts in energy level of a collective mode capable of producing observed effects it is hard to escape the conclusion that, as for a photon, we would expect just one indivisible experience of its environment. This might be counterintuitive but there are neurophysiological reasons to think it makes sense. The patterns of brain signals that represent the world almost certainly encode that representation purely in spatial relations because time is taken up with frame sequence. We are not expecting temporal aspects of the world to be represented temporally. Both movement and a sense of continuity are almost certainly encoded in space, just as they are on the page of a book. How that gets interpreted as time is a mystery, but perhaps no more than the taste of peppermint being encoded in spatial relations!

If only one of the two arguments existed – either quantum theoretic or neurobiological – for denying that an indivisible dynamic unit could perceive time evolution veridically, things might be moot. However, even if an excitation could perceive time as time the fact that there is no meaningful 'passage' of time within an excitation would mean that this would not be a 'veridical' sense of time passage anyway. Modern physics indicates that nothing 'moves' or even 'progresses in time' in an intuitive way.

Any claim that we can introspectively verify our sense of continuity also threatens to generate a paradox. To verify we would need to compare events of experience at different points in time to see if they 'joined up'. But that would involve 'cutting and pasting' in short term memory that would invalidate the verification.

In short, my conclusion is that Leibniz's analysis conflates the dynamic history of a collective mode with that of its component excitations. Having initially been tempted to think that a wave packet could provide a temporal width for experience by a mode I now believe it has to be abandoned. It is hard to blame Leibniz for not identifying a nicety of this sort when he very nearly got the story to work. Maybe he should have realised that he was overriding his own logic, but I suspect he was a lot nearer to the truth than any of his contemporaries.

The two-level analysis given above makes it easier to relate perception to the logical steps of Leibniz's computing automata. Within brain, sensory signals are presented stepwise as patterns of electrical potentials, to which responses are made, in between refractory periods. This fits with the idea of an automaton executing logical steps. At fine grain Leibniz;'s Law of Continuity will be obeyed, as there are no perfectly hard boundaries, but the process will be discontinuous in that each step reflects the identity of a new excitation within a mode.

It might be argued from introspection that our logical thoughts span more than a few milliseconds and perhaps up to a few seconds. It is conceivable that individual excitations might span across several refractory cycles within cells but it is equally likely that this is another temporal illusion along the lines discussed above.

Leibniz (1714) was aware of the unreliability of introspection and in this context had a concept of percepts comprising a vast number of subliminal 'petits perceptions' that again may threaten his account of indivisibility. These may not have a useful modern equivalent. Subpersonal or subliminal aspects of perception tend to be regarded now as events in early sensory pathways that do not pass through to events of conscious experience per se. Within events of experience we have little or no indication of what might be component meaningful signals. To the extent that Leibniz is saying that

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we are unaware of 'perceptual grain' he is right, but it is unclear that we can deduce much from this.

In conclusion, the two-level analysis given would seem to provide a satisfactory account of enduring 'seats of consciousness' in the form of collective modes but also a transition from percept to percept based on individual excitations that would make sense of both the fundamental dynamics and interruptions in sentience such as sleep.

The Importance of Microscopic Animalcules

Talk of excitations in biological material being monads might seem distant from the popular view of Leibniz's metaphysics. But why? Leibniz's mature dynamics follows, amongst other things, a visit to the microscopist Leeuwenhoek in 1676.

Three things may have stuck in Leibniz's mind after looking at magnified pondwater. Firstly, the microscopic world is full of motion – that could explain the powers of macroscopic things to engage in dynamic relations even when they appear static. Secondly, the microscopic world contains animalcules (today, cells) that buzz around as if powered by inexhaustible 'drive'. Even with lenses of the time he may have seen vibration created by beating of cilia. Thirdly, between motile animalcules there is yet more vigorous motion of tinier bodies: bacteria in Brownian motion.

Leibniz (1714) later conceives all reality in terms of units of invisible drive. He correctly deduces that drive operates at many scales, although suggesting scale gets smaller ad infinitum looks misguided, unless that translates as quantum foam. Explaining things at a microscopic scale would have been useful in 1680, when everything beyond brute collision appeared to be at a level we cannot see – the motion of heat, deformation of elastic bodies etc..

I wonder whether he may also have come away with the idea that the continuing drive in living things might specifically take the form of a hidden vibration, capable of guiding perception. This is the one case where Leibniz can identify a whole living body with a directly manifest unit of drive or monad. This would help explain why in *New Essays* he suggests human understanding is mediated by a vibrating membrane. Leibniz realised that human souls perceive through a local relation to brain tissue. The idea that the soul exists before conception as a 'spermatic animalcule' also suggests that seeing protozoa made Leibniz (1714, §74) think the true nature of animal units and monadic drive was at this hidden scale.

An interesting aspect of Leibniz's account of brain events in *New Essays* is that he makes vibration an action of membrane, with the monad perceiving patterns on the membrane. Elsewhere Leibniz (1694) talks of action as a property of monads rather than bodies, so should the vibration be the action of the monad? As I read it, Leibniz sees vibration as part of the phenomenal world. Action at the monadic level is the underlying 'primitive force'. This is consistent with the role of a phononic mode in our current account of vibration. Phonons are not particles hiding between atoms. They are mathematical patterns of drive.

Attributing subject status to a whole human body was always problematic. In material terms, there is no justification for including kidneys or toenails when neither appear to house subjectivity. Moreover, in terms of gathering information from the world, why exclude a blind man's stick or 'Otto's notebook' (Clark, 2008)? Nothing in biology points to the whole body as a basis of subjectivity.

Both Descartes (1649) and Leibniz understood this. Both conceive the subject as something associated with brain events, with a looser relation to the whole body in the sense of dominating its behaviour. Nevertheless, these Early Modern natural philosophers saw that an account of the human subject would need a *distributed* domain, in a way that emerging classical mechanics did not explain, but with no clues as to how wide they should go. If perceptions of a soul reflect rich patterns of events in tissue - more than just a point interaction - if an extended domain was allowed in brain, why not the whole body, even if the case was weaker since nerves appear to bring things to be perceived together in brain?

We might just about be able to relate acoustic modes in brain more widely. Acoustic modes relate to complex structures; the mode of a violin string also depends on violin body, soundpost and bridge. Acoustic modes within brain in theory exist within the context of the entire body. In practice, however, we can be reasonably sure nothing much would matter for collective modes in brain beyond very local tissue architecture and any wider extension would be irrelevant to the sort of function Leibniz had in mind.

The discussion here of modes that might support experiencing subject units in brains has focused on general arguments. A range of specific collective modes have, however, been invoked, and something should be said about plausibility. Fröhlich (1968) first proposed a role for modes within cell membranes but said little about their role. At much larger scale Vitiello (2001) proposed collective modes of synchronous oscillation across cortical neuropil.

Leibniz is not quite clear whether he is proposing a soul that perceives through many vibrating membranes or one. Moreover, although he believed in one dominant subjective soul, he believed it was surrounded by myriad other, if 'lesser', perceiving units. My reading of neurophysiology is that, however counterintuitive, soul units whose experiences we discuss as 'ours' must perceive an integrated set of signals laid out in *an individual neuronal dendritic tree* – implying that there may be millions of such units in a brain (see Edwards 2020; Edwards and Somov, 2023). As the catchphrase goes 'there is no one place in a brain where everything comes together'. Dennett (1991) was likely right that experience comes as 'multiple drafts', or copies. Neuroanatomy tells us that there are millions of similar cellular 'perceiving units' of apparently equal status that receive representations of the world and no larger scale sites of integration. The cytoskeleton provides the most plausible site for a stable

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collective mode that might mediate perception and be the target of anaesthetics (Craddock, 2017; Edwards, 2020). The counterintuitive implication is that human perceiving souls are not only evanescent but multiple in space as well as time.

If souls perceive through interactions in individual dendritic trees then Leibniz's interest in the role of the buzzing 'animalcule' or individual cell may be more radically confirmed than even he would have suggested.

General Discussion

The more I read Leibniz's account of fundamentals required for valid physics - i.e., metaphysics - the more I see cogency. Of recent commentators, both Arthur (2018) and Jorgensen (2019) emphasise Leibniz's link to natural science. I would go further; Leibniz was a scientist, who, like Feynman, understood that grasp of fundamentals is part of the toolkit. He took the representational nature of perception of a 'material' world into account, as modern neurobiologists do. Like Feynman, he might well have said 'Nature isn't classical, dammit'. His actual dynamic reality was the monad.

Leibniz's quest for the nature of individual perceiving dynamic units is as valid today as then. There must be such units since we find ourselves as examples. If physics is the study of what is really going on, the quest is within physics. Leibniz's cogent inferences about the nature of fundamental relating units remain sound. They cannot be arbitrarily defined aggregates. Perception cannot belong to networks of nerves, nor any closed 'information system' whose parts signal to each other. 'Combination' was always a non-starter.

Although the account in *New Essays* is brief, I suspect Leibniz (1765) identified a basis for human subjectivity close to the truth. Our perceptions belong to indivisible dynamic units associated with ordered structures within brain, where representations of the world are available as patterns of electrical potential and that the 'drive' that constitutes these units is of a sort that can underpin modes of oscillation/vibration in associated matter (Edwards, 2020).

I suggest Leibniz's principles should be applied in subtly different ways to at least two levels of individual. In the context of 'material bodies', being a true individual may involve two steps – perhaps recalling Leibniz's (1694,1695) system of primitive and derivative forces. The relation between monad and body may align with the simple concepts of Monadology but practical details may be far from simple – as illustrated by branches of field theory such as Goldstone theorem. For perhaps the simplest dynamic unit, a photon, dynamic indivisibility is rigid, transcending intuitions about evolution in time. The photon exists as a whole: period. Moreover, its energetic drive is fixed, as Leibniz wanted. In contrast, collective modes in condensed matter have dynamic continuity but are temporally divisible in that they can 'report' their dynamics via sequential interactions, with shifts in energy content. These modes are not indivisibles but are still intrinsic individuals, that endure diachronically.

Collectives such as phononic modes have a two-level hierarchy of interaction. A field asymmetry, for acoustic modes one of spatial directional order, brings the mode into being. This fits well with what Leibniz called an associated body, in which individual constituent molecules can change over time. A continuing structural pattern is associated with a constant mode of 'drive', in thermodynamics a new degree of freedom. Being 'the same thing' over time at this level depends on enduring asymmetry.

The term mode is associated by philosophers with Spinoza, who denied the existence of true individuals, claiming all phenomena were different aspects or modes of a unitary whole. Collective modes fit with this idea in being 'ways of acting' rather than indivisible individuals. Yet they are also have features that Leibniz claimed for monads.

Modes can be seen to interact with detailed patterns within the continuing asymmetry, but these interactions also form the (indivisible) interactions of individual component excitations. The mode can have minimum energy content in a ground state or intercurrent field perturbations can induce shifts in energy content. In operational terms this can be seen as a series of perceptions of surrounding world; each forming an individual excitation step but determined by the nature of the mode's 'drive' and how it couples with other fields. Leibniz's conception of a unit progressing through multiple perceptions or logical steps via internal drive may only apply to this sort of collective mode.

This brings us back to the core of Leibniz's (1686) metaphysics – the ways we attribute predicates to subjects in propositions and how dynamic elements within the universe can acquire information about the truth of those propositions. Leibniz's ontology is dynamic and, since it involves the acquisition of perceptions, epistemic – what things can know what about what. Modern fundamental physics is also about what can be known about what. It tends not to address what sorts of things know. Yet neurophysiologists can now apply physics to brains in ways that might answer that question.

For Leibniz, without access to modern physics or neurobiology, half-right answers were understandable. We have no excuse. We know the general form of dynamic units. Their relations do not combine, other than in the sense of constituting universal fields. We also know, however, that Leibniz was right that aggregates form ordered structures with *new* units associated with their global dynamics, so that individual units occur at all scales.

We should not try to relate the dynamics of a human perceiving soul directly to running and jumping, or even the cacophony of signal sending in a net of a billion nerves. As Leibniz (1695) hints in *New Essays*, a soul is going to perceive in a *single* relation to a complex pattern of active 'matter'. Any other cobbled together analysis falls apart. As William James (1893) put it: 'not a physical fact at all'. The task now is to identify where in the brain we can find *single* relations compatible with both biophysics and a rich event of experience.

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There may be a comforting irony in all this. Leibniz's Principles leave most in doubt his vision of souls as immortal. Modern biology indicates that Locke's (1689) idea of self, based on a narrative from memory, is closer to reality. Sentient dynamic units might endure in brains for years, but even the folding of membranes Leibniz built his picture of memory on suggest changes in structure that make truly unchanged units of drive unlikely. Immortality, if it is anything, will be the thread of a narrative passed, like the Odyssey, from soul to soul. But that being so, Leibniz may have achieved a sort of perfection in terms of what immortality there is. His work will probably be known for as long as knowing prevails.

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