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

Jonathan Edwards[1]

1 University College London, University of London

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Abstract

Conscious perception poses puzzles in relation to subject identity and continuity that Leibniz paid close attention to. Re-applying his principles in a modern context suggests three conclusions. Firstly, his search for fundamental indivisible (monadic) perceiving dynamic units looks to be as well motivated as ever. Secondly, modern physics suggests ways to avoid the temporal paradox raised for Leibniz by Russell, with events of experience being both distinct and part of a continuum. Thirdly, 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 something peculiar to certain types of fundamental dynamic individual with a constant pattern of 'drive' but variable energy content, typified by collective modes of field excitation in condensed matter. In simple terms, a local domain of the electromagnetic field may provide both the affordance that brings a particular collective mode into existence and, in addition, ongoing variations that can inform the mode about changing events to which the mode can respond in terms of shifts in energy content.

> *"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

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 the 'specious present', popularised by James (1893), 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 his *Critical Exposition of the Philosophy of Leibniz* (1900), Russell argues that, however powerful the logic, Leibniz's analysis fails through contradiction, particularly with regard to time. In simple terms, 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, it may be Russell's analysis that looks hidebound by logical niceties (see Arthur, 2018; Jorgensen, 2019).

Leibniz's principles can sound dogmatic and abstract but in intended context 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, in addition to 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 a possible solution 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 tantalisingly 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.*
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> *(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 that allows images to be interpreted in terms of innate concepts (perhaps multiplicity, 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 includes dynamic units with little resemblance to traditional concepts of ‘matter’. If such units could be perceiving subjects, crucial determinants of what could qualify are factors governing spatial and temporal domains and boundaries. Russell was probably right to suggest time is the more critical issue.

Modern Monads: Modes of Field Excitation

Leibniz’s (1714) monad was defined as a single indivisible unit of power, 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 ‘modes of excitation of fields’, once called ‘particles’, or in some cases ‘quasiparticles’. (All of these terms are potentially 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 mathematical pattern of ‘drive’ (disposition to change) arising in the context of (in harmony with) a gradient or asymmetry in one or more coupled 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 (have an asymmetry) a dynamic unit can arise in response – like a lightning bolt rebalancing unequal atmospheric charge.

This may sound abstract and obscure but many mode types are familiar as 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, generalised field theory recognises that modes arise with asymmetries at all scales. Vitiello (2001) pointed out 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 every-day phenomena like sound waves and electrical conduction in metals involve modes with domains far larger than atoms – including the Albert Hall.

Leibniz (1765) presents a soul as (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. I will return to the issue of multiplicity later but want to keep the discussion as general as possible. 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 co-ordinated neural oscillations. My own analysis has focused on individual cellular structures (Edwards, 2020). Leibniz perhaps hints at both.

In the simplest of terms, it would be nice to have a basis for some non-extended action or spirit unit 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. Mental life may seem far too rich to fit into anything biophysical, but we do know brain activity to be complex.

There has been a recent 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, which remains cogent. An indivisible point of view may involve a distributed spatiotemporal domain but not functional parts. 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 a '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 fully formed and to continue as a speck of dust after death. Modern physics probably holds to Leibniz's principles better than he; modern units of drive *must* 'reflect' or 'represent' the field gradients of their domains. An inner s orbital of an iron atom cannot mediate conductivity. (There is no tenant 'electron A' that can 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 will 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?

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 composed of 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 one thing suddenly starts as another stops. 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, consistent with empirical findings in the 1680s – elastic forces replacing rigid extension - and underpinned by the powerful 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. This implied a boundary line with an infinitely rapid change between no push and push. 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 close in but opposite gradients at the same place! Leibniz's law gives the *a priori* case for an Indeterminacy Principle. Spatial location must be 'vague' (Gerhardt, 1890; Arthur, 2018, p284). Profiles of dynamic properties must tail off – in line with Gaussian profiles of 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, domains covered by 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'? 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 particularly close harmony – perhaps in modern terms 'entangled' subatomic modes, all with trivial 'tails' out to infinity. The soul is then a higher monad that inherits the non-trivial aggregate domain (s) as a single distributed indivisible action unit with a similar trivial or confused relation to the rest of the universe. 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.

Continuity and 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 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 resolution of the 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 '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 the one it is going to be. Only in some other 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 odd 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 subsequent events involved in how it is finally 'measured', and apparently on for ever, suggests to many 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.

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 broader context of this universe being the one it is and Aristotle being 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. Whether we have contradiction is uncertain, but a bit more explaining is needed.

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 of which perhaps having a profile with tails reaching back and forth? Or is there a third solution? I shall return to this later.

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 were 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 on grounds that we may not think photons perceive. However, our reason for thinking that animal subjects perceive is that we see behaviour indicating that something within is informed or influenced by environment. In operational terms we have the same for a photon; measurements indicate that it has arisen from influences or necessities provided by local environment. It behaves as if informed by a lens or a pair of slits in a screen. 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', i.e., 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' to us is, using Feynman's (1990) analysis, dependent on all notional 'paths' the photon might take from genesis to annihilation. A photon from a star gives up information about a vast spacetime domain, never about 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 a mode of excitation of a field, whether a photon, an actualised electron orbital or a free electron mode, interacts with its environment and thereby potentially makes available a measurement, it ceases to be that excitation and the 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 the world that could contribute to history and be known about.

There is, however, a complication. The dynamic units just mentioned are simple excitations that do not change energy content, or amplitude, over time. In condensed matter modes of excitation of fields can be collective, reflecting correlated patterns based on large numbers of notional energy subunits. Vibrational modes based on phonons are the most familiar example. Collective modes of arrays of excited electrons are another. (At this stage of the discussion, I am deliberately avoiding analysis of specific options for collective modes that might underlie 'our' subjectivity, to concentrate on Leibniz's contribution in general terms. I address the topic elsewhere (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 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 of time while the amplitude varies as notional energy-bearing subunits come and go. The mode of vibration of a violin string (open position) remains constant over time but its amplitude varies as the string is played. Unlike the photon the string can tell us about what has been happening 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 imply a 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 that number is, or when it changes. 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.

Trying to get information about dynamic units in a way that violates dynamic indivisibility ought to be a false quest, if Bohr’s principle holds good. On the other hand, as Feynman et al. (1964) indicate, measurement and determinacy are not all or nothing; they may be partial. Moreover, modes of excitation carry different sorts of information, some more accessible than others. Spin values tend to be ‘hidden’ at quantum level whereas charge contributes to field strength at classical level.

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 is 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

An alternative interpretation is that an enduring collective mode is not a fundamental unit, because it is constantly changing its identity. Individual evanescent ‘quanta’ might be what perceive, but these units probably have no existence other than as a notional basis for the total energy of the mode. Perhaps the mode is reborn every time it changes amplitude and so perception might belong to each reincarnation separately. Then the difficulty is that there may be no fact of the matter exactly when rebirth occurs.

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 that endure for months or years and possibly for much of a lifetime. They can relate to environment in two ways. One is to reflect stable asymmetries. The other is to reflect fluctuations in field patterns within those asymmetries and respond by shifting energy content. Each new response can be considered a ‘choice’. This would be incompatible with the dynamic indivisibility we attribute to a photon but would be consistent with a Leibnizian ‘soul’. All choices might not seem entailed in the unit from creation but at least they would in Leibniz’s view from outside of time - *qué será, será.*

In this situation we can ascribe perceptions to the enduring unit even if strictly speaking perceptions may be tied to periods between exchange of energy units - notional ‘quanta’ (phonons or excitons). This might neatly explain why our perceptions seem to be ours and yet fleeting and irretrievable other than through shadowy replay in memory. This view may sound like Locke (1689), but the justification comes from 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 is directed to an actual, achieved, end; 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 just might. After all, a sense of purpose must somehow relate to 'objective' dynamics. The trouble is that our perceptions of purposes may be well-founded illusions like everything else – not *quite* what they seem!

Temporal Width

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. Arbitrary material aggregates need not have definable duration in this sense. This fits with modern physics requirements for field-based interactions. Modes of excitation arise from field patterns in both space and time. Nothing exists in space alone. Forget objects.

What is up for debate is whether a perceiving subject lasts just one percept, to be replaced by another, or endures from percept to 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 how apparently discrete percepts can fit into a principle of continuity and, if discrete, what temporal width is determined by. The law of continuity rules out a sequence of discontinuous 'frames' like a cine film; how would a current episode co-exist with the temporal 'tails' of past and future episodes? But perhaps incompatibility between continuous and episodic is not so simple.

A more promising approach may be 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 considered as if a Gaussian wave packet constantly recycling through the ordered structure that it inhabits. Trying to envisage events at the quantum level is ill-advised but a simple analogy may work here. To avoid any 'preferred position' in wave packet profile one can think of it as a corkscrewing. At its centre a corkscrewing looks unchanging. Let the corkscrewing run up and down a violin string as a Gaussian pulse, with a length ten times that of the string. We have a near constant static helix profile. But the packet takes the form of a brief time window progressing continuously through time.

Thus, although it might seem that multiple distinct experiences imply temporal divisibility and hence discontinuities, they may not. If experience covers a domain in the form of a wave packet either as a quantum theoretic 'wave function' or as given by classical standing wave dynamics, 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 will be possible to distinguish a series of distinct states with different contents despite forming a continuum.

The idea of a wave packet of perceptive domain progressing through spacetime, always tailing off to infinity but never overlapping, allows Leibniz's idea of 'simple substance' to be satisfied without contradiction. A wave packet constantly tracking back on itself within a material body can be a constant mode of change. Its life history is one continuous whole. Experiences, or perceptions of outside influences, although distinct, are not *separate parts* of this whole. For even the smallest shift in the centre of the domain of view the perspective changes. Combination across discontinuity does not arise; any idea of 'division' is a category error.

One might ask whether, since a photon's dynamics also has a wave packet form, even a photon might go through a continuous sequence of perceptions. On the other hand, with the only outcome for a photon being release of energy and information at the one event of annihilation, contingent on the totality of mathematical relations *throughout* its 'possible paths' the situation looks significantly different.

Logical Steps and 'Petites Perceptions'

The compatibility between distinct perceptions and continuity argued above may not quite satisfy a Leibnizian (1714, §14) conception of monad moving from percept to percept, especially if compared to the logical steps of a computing automaton. In some ways our thoughts do seem discrete.

Arthur (2018) gives a cogent analysis. Leibniz sometimes talks as if perceptions form a discrete series, but he also emphasises (1710) that conscious perceptions (apperceptions) arise through ongoing integration of myriad individually imperceptible sensory signals ('petites perceptions'). His law of continuity applies to dynamics, involving force or energy. There is no particular reason why this should have to apply to logical steps arising from the integration of microphysical events. Logic is more or less by definition discrete, but its instantiation in dynamics might not be.

Thus, instantiation of logical steps in a computing automaton might appear at first sight physically discontinuous. Within brain, sensory signals are presented stepwise as patterns of electrical potentials interspersed with quiet refractory periods. Nevertheless, at fine grain all the dynamic interactions will have continuous profiles in keeping with Leibniz's requirement of no infinite gradients. In modern physics modes of excitation may come and go but the profile of each always has 'vague' edges. Even in a computer the logical steps need not break the dynamic continuity.

A practical neurobiological question about temporal width that might be empirically tractable is whether our apperceptions are punctuated strictly by cycles of neural firing and refractoriness, about every 20 milliseconds, or integrated over periods closer to a second, as might seem subjectively the case. Longer term integrative processes may prove relevant. The ability to sense a whole tune in a specious present might tempt us to think that apperceptions have time frames running into seconds. The content they represent might, but then we can also contemplate much longer durations. Maestro Antonio Pappano likely contemplates Tristan and Isolde in entirety (5 hours) while conducting. Introspection suggests that our sense of a tune consists of a sense of the whole, or even a next answering phrase, *simultaneously* with a sense of a passing note. I think this is analogous to sensing the colours of a Bonnard interior while at the same time sensing both the whole scene and its ‘Bonnard-ness’. The specious present in temporal content terms does not look a good guide to the duration of an event of perception but it may be a useful reminder that for an event to exist, it must have duration, even for purely spatial representations.

The Importance of Microscopic Animalcules

Talk of collective modes as dynamic individuals in biological material may seem alien to the accepted view of Leibniz’s metaphysics. I think this would be a mistake. Leibniz’s mature conception of dynamics follows, amongst other things, a visit to the Hague in 1676 where he meets the microscopist Leeuwenhoek.

Three things may have stuck in Leibniz’s mind after looking at pondwater through Leeuwenhoek’s microscopes.

Firstly, the microscopic world is full of motion – that could explain the powers of macroscopic things to engage in dynamic relations even when they often appear static.

Secondly, the microscopic world contains animalcules (these days, cells) that buzz around as if powered by inexhaustible ‘drive’. Even with lenses of the time he is likely to have seen vibration created by beating of myriad cilia.

Thirdly, between motile animalcules there is yet more vigorous motion of tinier bodies: bacteria dancing 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 the scale goes smaller ad infinitum looks misguided, unless you translate it as quantum foam. Explaining things at a microscopic scale would have been useful when in 1680 everything beyond brute collision had to be explained at a level we cannot see – the motion of heat, deformations of elastic bodies etc..

What may have been less evident in his writings is that he is likely to have come away with the idea that the continuing drive in living things might be manifest as a hidden vibration, capable of giving rise to larger scale motion and thereby guiding perception.

This is the one situation where Leibniz can identify a whole living body with a directly manifest unit of drive or monad. It gives him a concrete example of what monadic drive might do – power vibration. This would 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 it was at this hidden scale that one can see the true nature of animal units and monadic drive.

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 the signals falling on the vibrating membrane. Elsewhere Leibniz (1694) talks of action as being 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 beneath: operation of a power. This is consistent with the role of a phononic mode in our current account of vibration. Phonons are not extra particles hiding between moving atoms. They form a mathematical pattern of drive or necessity. In the same way a valency electron mode in a metal is not a taxi cruising around waiting for a ride from a voltage. It is a mathematical pattern of drive, in operation, envisageable only in terms of the likelihood of its consequences.

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 functional interaction with information from the world not only do kidneys seem uninvolved, but why should we exclude a blind man's stick or 'Otto's notebook' (Clark, 2008)? Nothing in biology points to the whole body being the basis of a subjectivity.

Both Descartes (1649) and Leibniz seem to have understood this. Both conceive the subject as something associated with events in brain, with a looser relation to the whole body in the sense of dominating its behaviour. Behaviour might seem to be a different matter from subjectivity but at least for Leibniz (1714, §14) there was a belief that the two were inextricable.

Nevertheless, these Early Modern natural philosophers realised that an account of the human subject would need to involve a *distributed* domain, in a way that emerging classical mechanics did not explain, but with no real clues as to how wide they should make the domain. If perceptions of a soul reflect rich patterns of events in living tissue - more than just a point interaction - then 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? For a protozoan matching of domain and drive would be transparent. It is perhaps unsurprising that Leibniz does not venture a more specific account for the trickier human case.

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

The discussion here of modes that might be experiencing subject units in brains has been focused on general arguments about continuity in the face of shifting perceptions and the role of varying energy content of collective modes. A range of collective modes have, however, been invoked, and something should be said about plausibility. Fröhlich (1968) first proposed a role for modes within bilamellar lipid membranes. At much larger scale Vitiello (2001) proposed collective modes of synchronous oscillation across cortical neuropil.

Leibniz does not make it 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 2005; Edwards, 2020). As the catchphrase goes 'there is no one place where everything comes together'. Dennett (1991) is likely right that experience comes as 'multiple drafts', or copies. The cytoskeleton provides the most plausible site for a stable collective mode that might mediate perception and be the target of anaesthetics (Craddock, 2017; Edwards, 2020). (Although actual cell membranes may contribute to a local acoustic substrate, their synaptic spines probably make them too structurally heterogeneous and damped to be the primary substrate itself.)

Individual dendritic trees are where information is integrated for computational processing. Integration does not occur anywhere else, despite many people seeming to assume it must. In my view there is no justification for positing a perception relation at a larger scale when neuroanatomy says there is nothing to make operational sense of it – but suggestions are welcome!

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 fundamental concepts is part of the toolkit. He took the representational nature of perception of a 'material' world into account, as modern neurobiologists do. He might have said 'Nature isn't mechanical phenomena, dammit'.[1] His true dynamic reality was the monad.

Leibniz's quest for the nature of individual perceiving dynamic units is as valid today as it was 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 never went away. They cannot be arbitrarily defined aggregates. Perception cannot belong to aggregate networks of nerves. Nor can it belong to a closed 'information system' whose parts signal to each other – nervous systems are not closed, and each part would perceive something different. 'Combination' was always a non-starter.

Although the account of 'understanding' in *New Essays* is brief, I suspect Leibniz (1765) identified a basis for human subjectivity that may be close to the truth. The suggestion is that our perceptions belong to indivisible dynamic units associated with complex ordered structures within brain, where representations of the world are available as patterns of electro-magnetic potentials and that the 'drive' that constitutes these units is of a sort that can underpin modes of oscillation or vibration in associated matter (see Edwards, 2020).

There are two points on which I think Leibniz's analysis might be refined, without losing the validity of basic arguments. The first is to clarify how a sequence of distinct apperceptions or ideas can be compatible with continuity both in terms of dynamic profile (Gaussian curve) and endurance of a dynamic individual. I have argued above that the emergence of what we experience as distinct conscious thoughts and logical progressions is consistent with such continuity at a fundamental level.

The second point is the suggestion that Leibniz's principles should be applied in subtly different ways to at least two levels of individual. Being a true individual may be a matter of degree – recalling Leibniz's (1714, §82) subclassification into bare monads and rational souls. For perhaps the simplest unit, a photon, continuity and dynamic indivisibility are 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 repeatedly via sequential interactions, involving shifts in energy content. These modes might not be deemed true individuals but, in a sense, they endure across times more 'diachronically' than the photon.[2]

Collectives such as phononic modes have a two-level hierarchy of interaction. A field asymmetry, for acoustic modes 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. What matters is a continuing structural pattern that can associate with a mode of 'drive'. Being 'the same thing' over time depends on an enduring structural asymmetry, not being in the same atoms in the same place.

The mode can also interact with detailed patterns within the continuing asymmetry. It 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 continual process of changing perception of surrounding world; moreover, a changing perception determined by the nature of the mode's 'drive' and the way it couples with other modes such as photons.

Leibniz's conception of a unit progressing through multiple perceptions via internal drive may only apply to this sort of collective mode. There is no two-level hierarchy for the photon. However, things might be yet more complex. Quantum theory requires that certain properties of a dynamic unit X, a mode of excitation, cannot be known, unless the mode changes identity to a new mode. Other properties may be known, at least indirectly or in general terms. The red flame of burning calcium tells us about electron orbital modes appearing and disappearing, but it also implies other modes are nearby. As indicated by Feynman et al. (1964), 'determinacy' in quantum theory is a subtle and shaded matter.

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 the question.

For Leibniz, without access to modern physics or neurobiology, mistakes were understandable. We now have no excuse. We know the general form of individual dynamic units. Their dynamic 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 that have *new* dynamic units associated with their global dynamics, so that individual units occur at all scales. This is not about 'complex systems'. The dynamics of a global mode are *not* the combined dynamics of parts. In cases like the violin string, the dynamics of the global acoustic unit might seem to be accounted for by molecules moving to and fro – but it isn't quite. For units that determine latent heat, crystal shapes and electrical conductivity the global dynamics have entirely novel features.

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 appropriate *single* relations compatible with biophysics.

I would like to think there is a comforting irony in all this. Leibniz's Principles leave most in doubt his vision of souls as immortal. Modern biology makes it likely 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 continuation of a narrative passed on 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.

Footnotes

[1] Alluding to Feynman's 'Nature isn't classical, dammit.'

[2] A further subtlety is that modes can exist as 'families' that, if tightly enough correlated, function as single entities. Exciton modes may be coupled to acoustic modes. Acoustic modes may involve a series of harmonics. Spread of energy within a mode 'family' may vary. Identity may be complex.

References

- Arthur, R.T.W. (2018) *Monads, Composition and Force*, Oxford: OUP.
- Clark, A. (2008) *Supersizing the Mind,* Oxford: OUP.
- Craddock, T.J.A., Kurian, P., Preto, J., Sahu, K., Hameroff, S.R., Tuszynski, J.A. (2017) Anaesthetic alterations of collective terahertz oscillations in tubulin correlate with clinical potency, *Scientific Reports*, **7** (1), 9877.
- Dennett, D.C. (1991) *Consciousness Explained.* Penguin Books.
- Descartes, R. (1641) *Meditations on First Philosophy,* English translation: https://www.earlymoderntexts.com/assets/pdfs/descartes1641.pdf
- Descartes, R. (1649) *Passions of the Soul,* English translation:

https://www.earlymoderntexts.com/assets/pdfs/descartes1649part1.pdf

- Edwards, J.C. (2005) Is Consciousness Only a Property of Individual Cells? *Journal of Consciousness Studies*, **12** (4-5), pp. 60-76.
- Edwards, J.C. (2016) Leibniz and Telicity. In: *Proceedings, 10th International Leibniz Congress, V. 1*. Hannover, Gottfried Wilhelm Leibniz Gesellschaft.
- Edwards, J.C. (2020) Quantum-level experience in neural dendrites: an interpretation-neutral model. *J. Consciousness Studies,* **27** (11-12), 8-29.
- Feynman, R., Leyton, R. and Sands, M. (1964, 2005) *The Feynman Lectures in Physics, III, ch1* Boston: Addison-Wesley.
- Feynman, R. (1990) *Q.E.D.,* New York: Penguin Press Science.
- Gerhardt, C.I. (1890) *Die Philosophische Schriften von Gottfried Wilhelm Leibniz,* §IV, 512-13. *De Ipsa Natura.* Berlin: Weidmann.
- James, W. (1893) *Principles of Psychology,* New York: Holt & Co.
- Jones, M. (2018) Calculating Machines. In Antognazza, M.R. (ed.) *The Oxford Handbook of Leibniz,* Oxford: O.U.P. pp 509-525.
- Jorgensen, L. (2019) *Leibniz's Naturalistic Philosophy of Mind,* Oxford: OUP.
- Leibniz, G. (1678, 1994) De Corporum Concursu. In Fichant, M *G.W. (ed.) Leibniz: La Réforme de la Dynamique,* Paris: J.Vrin
- Leibniz, G. (1686, 1998) Discourse on Metaphysics. In Woolhouse, R.S. and Francks, R. (eds.) *G.W. Leibniz: Philosophical Texts,* Oxford: OUP.
- Leibniz, G. (1694, 1998) Reflections on the Advancement of True Metaphysics. In Woolhouse, R.S. and Francks, R. (eds.) *G.W. Leibniz: Philosophical Texts,* Oxford: OUP.
- Leibniz, G. (1695, 1998) Specimen dynamicum. In Woolhouse, R.S. and Francks, R. (eds.) *G.W. Leibniz: Philosophical Texts,* Oxford: OUP.
- Leibniz, G (1710, 1951) *Theodicy,* §393. London: Routledge and Kegan Paul Ltd.. Available at Project Guthenberg. https://www.gutenberg.org/files/17147/17147-h/17147-h.htm
- Leibniz, G.W. (1714, 1998) Monadology. In Woolhouse, R.S. and Francks, R. (eds.) *G.W. Leibniz: Philosophical Texts,* Oxford: OUP.
- Leibniz, G. (1765) *New Essays on Human Understanding,* translated by Remnant, P. and Bennett, J., Cambridge: CUP.
- Locke, J. (1689) An Essay Concerning Humane Understanding. At https://www.gutenberg.org/files/10615/10615-h/10615-h.htm
- Russell, B. (1900) *A Critical Exposition of The Philosophy of Leibniz,* London: Routledge.
- Vitiello, G. (2001) *My Double Unveiled,* London: John Benjamins.