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The neurology of time

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ABSTRACT

This investigation unifies and explains the different characteristics of time by carefully examining the stepwise construction of an internal model of the external world. An attempt to clarify the nature, origin, and types of time from a neurological perspective is heterodox, but, since the external world can be known only as an internal reconstruction, and since the reconstruction machinery is neurological, this novel approach may be heuristic. It will be seen that the origin of time is intimately related to sensible objects — a relation traditionally considered to be unequal or nonexistent. Since the birth of western philosophy in ancient Greece, an understanding of objects and time has been sought in their ontology —i.e., whether they are real or ideal— and as a consequence their relationship, if any, has been subordinate. However, the process of internal reconstruction demonstrates that objects and time are complementary in the rigorous sense of the term—both arise from a single neurological process. This common origin suggests a hierarchy of types of time concomitant with a hierarchy of increasing generalization of objects. The elements of this hierarchy will be seen to correspond to types of time that have been previously identified.

KEYWORDS: time, neurology of time, origin of time, nature of time.

INTRODUCTION

The nature and origin of time have been topics of scientific and popular interest for millennia. Within these discussions, a consistent source of confusion is the conflation of several distinct aspects of temporality, presumably as a result of their inclusion under the common term —"time". The least ambiguous appearance of time is as a mathematical variable in physical theories, and it may seem strange to seek a general explanation within the medical science of neurology. However, knowledge of the external world can only be obtained through an internally constructed model —including all physical theories and their components— and the substrate of that internal model is neurological.

The fundamental elements of physical theories are defined by their characteristics within the theoretical structures. When the explanatory power and predictive accuracy of a theory is demonstrated, its component elements, as defined, tend to be accepted as real. One result of this process is what has been called the disappearance of time[1]. In the twentieth century, time as defined in the theories of relativity has banished the notion of a universal 'now', and has been incorporated on a nearly equal metaphysical basis to space[2]. Even more destructive to a unification of the experiential and natural aspects of temporality have been the advances in dynamical quantum theories. A Lagrangian, or 'action', approach—first devised by Richard Feynman (1918-1988) in his pioneering work on

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1. "... it would only be a straightforward continuation of the development from classical physics to relativity theory, if this last objective remnant of time too were to disappear". K. Gödel (unpublished) in [1] p.39.
2. The sole factor distinguishing time from space is the sign in the Minkowski metric.

quantum electrodynamics (QED)—defines a frozen spatiotemporal universe in which paths directed forward and backwards in time are essential for calculation of finite interaction matrix elements[3]. Though Hamiltonian formulations of QED have also been proposed[4], these have proved less heuristic than Feynman's sum-over-paths technique in the development of complete unification schemes such as string theory[5].

The progressive exclusion of the experiential character of time has been disturbing to some philosophically minded physicists and mathematicians. In particular, Kurt Gödel (1906-1978) believed this fact alone indicated that time in our universe cannot be real[6]. Whether real or ideal, the concern with temporality has most often been ontological. Clearly though, the reality of time as expressed in modern physical theories is progressing in an incorrect direction for a unified explanation of its diverse aspects. An important part of this approach to a unification of experiential and natural time is that it is independent of ontology. That is, the following discussion is valid whether or not time is real or ideal.

This analysis demonstrates that different characteristics of time emerge as a natural consequence of an internal reconstruction of the external universe[7]. It will show that sensible objects and time are complementary in the rigorous sense of the term — both arise from a single process. This common origin suggests a hierarchy of temporal types concomitant with a hierarchy of increasing generalization of objects. The elements of this hierarchy will be seen to correspond to previously identified aspects of time.

Evolution of the idea of time

Time, as presently understood, includes at least three distinct characteristics[8] — duration or persistence, a relational structure of before and after (B-series), and the *nunc fluens* of past, present, and future (A-series)[9]. The evolution of the idea of time in western natural philosophy can be seen as the amalgamation of duration's metaphysical independence from sensible objects with the measurability of the B-series, and the denial of the A-series. The character of the different aspects of time, and the process by which they have reached their present status, are best appreciated by a brief historical recapitulation.

For the pre-Aristotelian Greeks, duration was not a part of time and was by definition unmeasurable. It was considered to be an attribute of an undifferentiated pre-universe and was therefore metaphysically independent of all elements of the perceptible universe[10]. Time (chronos) was, on the other hand, defined as the measure of motion and could not exist in its absence. Thus, time was a

3. "This view is quite different from that of the Hamiltonian method which considers the future as developing continuously from out of the past. Here we imagine the entire space-time history laid out, and that we just become aware of increasing portions of it successively" [2].
4. See Schwinger [3] and Tomonaga [4]. The different approaches to QED were shown to be equivalent by Dyson [5].
5. See [6].
6. He demonstrated this by creating a rotating universe solution to the field equations of general relativity in which time, as we know it, is impossible. Gödel's argument is that if general relativity is the best description of our universe, and if another universe consistent with general relativity is possible that does not allow time, then temporality must be inessential, and hence ideal. See Gödel [7] p.202.
7. How external temporality is reflected in sensory data is the only ontological question about time that is germane to the present argument. For the present purpose, it is possible to remain agnostic about time's reality or ideality, however, since I will show that the types of time can be explained without reference to its ontology.
8. Other types of time have been identified. See [8] for a complete discussion.
9. JME McTaggart (1866-1925) in [9] separates time into a fixed universal B-series of before and after, and a perpetually flowing universal A-series of past, present, and future. McTaggart's A- and B-series are universal in the sense that they exist independent of our perception of them, though he used this fact to attempt to prove time is not real. In his system, duration is incorporated into B-series time. McTaggart's classification will be used in the rest of this paper, though the A-series as here defined cannot be universal.
10. "... it was movement or duration without beginning, end, or internal division - not time ... but only the shapeless and unformed raw material of time..." [10] vol. I p340.

metaphysical subordinate to sensible objects[11]. A- and B-series time are arguably present in the philosophies of Plato and Aristotle, although there is no recognition that these two characteristics are separable.

Duration, as a principle distinct from time, can be traced from the Milesian Anaximander (c.600 B.C.E.) through Pythagoras (c.570-c.500 B.C.E.) and the Pythagoreans, to Plato (427-347 B.C.E.). A common belief of these philosophers is that the perceptible universe is formed from a timeless primordial material that is in sempiternal, unmeasurable, motion. Duration is a fundamental property of this primeval substance. Anaximander was, like the other Milesians, a monist who believed the universe is composed of a single element (*arche*), which he termed the *apeiron* (unlimited)[12]. The *apeiron* is timeless, though constantly moving[13]. Out of the *apeiron* is distilled the physical universe, and time appears as measurement of the orderly motion of the heavenly bodies[14]. Anaximander does not describe how an undifferentiated and unlimited *arche* becomes differentiated and limited, but this problem is explored by Pythagoras and the Pythagorean school. The Pythagoreans believed the *apeiron* is unformed matter and unformed time, not delimited by number or structure. The *peras*, or limit, by drawing from the *apeiron*, imposes number that forms the structure of physical objects, and the measure that is time[15]. Plato believed that motion existed before the universe in an unmeasurable and timeless chaos[16], while time is the measure of motion and came into being with the perceptible universe[17].

Aristotle (384-322 B.C.E.) rejected the existence of a primordial *arche*, i.e., he believed the sensible universe is uncreated and eternal[18]. In this he followed the presocratic philosopher Parmenides (c.515-c.450 B.C.E.)[19]. He therefore did not accept a metaphysically independent notion of duration separate from time. Instead, his arguments appear to define duration as a standard measure, i.e., a B-series element[20]. Thus, at the beginning of western philosophy, polar positions on time and duration were posed—a metaphysically independent duration, unmeasurable and separate from B-series time, and duration that is incorporated in B-series time, metaphysically subordinate to sensible objects.

Time as the measure of motion is B-series time. No extant comments on a potentially divisible structure of time (A-series and B-series) exist before Plato. In Plato's dialogues, and to a somewhat greater extent in Aristotle, recognition of A-series temporal characteristics first appear. There is no clear distinction between the A- and B-series, however, and even their presence is subject to some ambiguity. Plato recognizes past, present, and future as aspects of Becoming, and refers to time as a "... movable image of Eternity"[21]. To the extent that this refers to a *nunc fluens*, Plato can be said to have identified the A-series. However, in the next passage, he identifies these

11. For the Greeks, a universe of objects was conceivable without time, but no universe of time was possible without objects. Motion without time was not intrinsically contradictory, but time without motion was impossible. Cf. ibid. p.338.
12. For Thales the arche was water, for Anaximenes, air. See [11] p.22-27.
13. Cf. [10] vol.I p.337.
14. Cf. *ibid.* p.87.
15. [12] p.46.
16. Timaeus 30 A [13] p.55.
17. Timaeus 37 D,E [13] p.77.
18. On the Heavens I, xii, [14] pp. 111-129.
19. Parmenides rejected the notion of apeiron, recognizing that the physical universe required an external source upon which to draw only if it was incomplete in itself. He consistently emphasizes the peirata, or limits, as the ultimate timeless reality of objects and suggests that change or becoming is an illusion - as is time which is the measure of change. For a discussion of Parmenides' cosmogony, see [10] vol. II p.48.
20. See [15].
21. Timaeus 37D *op. cit.* p.77.

characteristics as actual motions delimited by number and hence a true A-series is not defined[22].

Evidence for a recognized *nunc fluens* is stronger in Aristotle than Plato, though it is still equivocal. Aristotle perceives an asymmetry between past and future wherein the past is fixed and the future is substantially undetermined[23]. This progressing asymmetry is interpreted by some as McTaggart's A-series[24]. Though this characteristic is necessary for McTaggart's A-series time, it is not sufficient. For example, the time defined in a Hamiltonian formulation of QED evolves continuously from fixed past to incompletely determined future, but because it is relativistically covariant, it cannot specify a unique 'now', and therefore cannot be an A-series.

In summary, the Greeks recognized atemporal duration as a metaphysically independent entity, and B-series time as the measure of motion, which is metaphysically dependent on objects. Whether Plato and Aristotle recognized A-series time is problematic. There is some evidence that both correctly identified characteristics of an experiential *nunc fluens*, but these characteristics are inextricably entwined with measurability and are not unambiguously stated.

The next advance in the natural philosophy of time defines a B-series time nearly independent of objects, thus retaining measurability while approaching the metaphysical independence of duration. This was accomplished by the Scholastic philosopher John Duns Scotus (1266-1308). Duns Scotus amalgamated (B-series) time and duration by using a concept of potential time. He insisted that potential time exists even in the state of absolute rest, and the duration of that rest could be measured[25]. However, since the existence of time still depends on the potential for objective motion, Duns Scotus did not completely free temporality from its dependence on objects[26]. Though he does not explicitly discuss A-series time, his successor, Peter Aureol (1280-1322), who adopted the idea of potential time, did mention A-series characteristics[27]. As with Plato and Aristotle, however, he conflates A- and B-series elements.

The advance to a modern view of the natural philosophy of time occurs by the complete separation of measurable time from objects, incorporating the metaphysical independence of duration. This first appears as part of the physics of Isaac Newton (1642-1727) whose natural philosophy rests upon three fundamental metaphysical principles - absolute motion, absolute space, and absolute time[28]. Absolute time is the measurable time of universal physical theories and "...flows equably without regard to anything external, and by another name it is called duration"[29]. In other words, absolute time is an amalgam of duration's metaphysical independence and B-series' measurability. A-series time is not included in this definition (except as conflated in the term 'flows'), but is probably part of what Newton calls apparent or common time. Though Newton's philosophy is not comparable in quality

22. "... 'was' and 'will be' , on the other hand, are terms properly applicable to the Becoming, which proceeds in Time, since both of these are motions. ... Becoming has attached to the things which move in the world of Sense, these being generated forms of Time, which imitates eternity and circles round according to number". Plato, *ibid.* 38A p.77.
23. On the heavens I, xii *op. cit.* p.127.
24. Cf. [15].
25. "For even to this uniform immobile existence there corresponds a proper measure, which is time" [16]. Question xi, 23 p.263.
26. "... even if no body is in movement, a body can always behave in the same fashion, while being capable of behaving in one fashion or another... There corresponds to this invariable disposition a proper measure which is a time" [16] p.296.
27. "On the other hand, the past and future, ... have no being if the mind does not conceive them. Therefore, ... time and movement are beings only in the mind". P Aureol in [17] pp.300-301.
28. The earliest statement of these principles is probably in the "De gravitatione et aequipondio fluidorum". See [18] pp.121-156.
29. [19] p.6.

to his physics[30], the notion of a time that is measurable, independent of all else in the universe, and excludes the A-series, is retained in physical theories to this day.

In summary, the evolution of the idea of natural time has been characterized by a consistent pattern — it has been progressively separated from its dependence on objects while maintaining its measurability. The experiential aspects of time have been suppressed, leaving a temporal structure in modern physical theories in which commonly recognized characteristics have disappeared. The following section will show how to retrieve the experiential character of time while retaining duration and the B-series. The sequence of duration, B-series, and A-series appear as elements of a hierarchy corresponding to a similar hierarchy of objects and concepts.

Complementarity of objects and time

The perspective of the following is epistemological and evolutionary[31]. According to this argument, knowledge begins with sense perceptions but is not limited to these perceptions. The *a priori* aspects of knowledge refer not to specific things that are known, but rather to a functional necessity imposed by the structure of the human organism[32]. In addition, knowledge is assumed to be inductively hierarchical—similar to Aristotle's perspective[33]. This development suggests that the same generalizing function producing concepts from sensible objects also forms sensible objects from undifferentiated sensory data. It is in this latter process that the complementarity of objects and time is found.

The human sensory apparatus provides a discrete series of 'images' of the ambience[34]. The discrete nature of these global percepts is fundamental[35] and can be best appreciated by an example of visual processing. If visual perception were continuous, then the illusion of continuous motion in a movie would be impossible since its interstices would be perceived. But, these discrete, multi-modal sensory constructs are unrelatable perceptual instants. The perceived continuity of discrete, undifferentiated global percepts requires a generalization that identifies equivalences in their elements[36].

By identifying an equivalence of specific elements in separate global percepts the process of generalization creates an object and that object's time. Each object is an equivalence class formed by an equivalence relation among elements of the global percepts. Merging elements of separate global percepts "squeezes out" their separateness, since by inducing that the elements are the same object, whatever causes their separate appearance must be excluded. Thus, by forming the category of object, 'simultaneously' an additional category is formed - the category consisting of the separateness of the global percepts of the object.

The formation of any single object, by an operation of inclusion (sameness), is coupled to

30. For example, there are difficulties in reconciling the notion of absolute motion and absolute space. Cf. [11] vol.V p.154.
31. The evolutionary perspective is essential so that the stages of evolution can be seen to arise successively through phylogeny. Thus it is only the simplest cases of objects and concepts that are considered and not the higher-order abstract concepts of modern scientific or philosophic discourse. This investigation is focused on the emergence of temporality in the earliest stages of mental evolution.
32. This is also the viewpoint of Copleston [11] vol.VI p.57 and is implied by Kant [20] p.25 when he states that *a priori* knowledge results from the "formal capacity of the subject being affected by objects".
33. "Clearly it must be by induction that we acquire knowledge ... , because this is also the way in which general concepts are conveyed to us by sense perceptions". Post. Anal. II, xix, 100b [21] p.261.
34. This metaphor is not accurate in the sense that an image normally presupposes a completed form and someone to look at it. The problems with this type of 'Cartesian theater' are discussed in detail in [22]. His argument is not relevant to the present development.
35. Grünbaum [23] has emphasized the 'atomistic' nature of experience, and Whitrow [8] p.74, defines a 'mental moment' as the limit of perceptual distinguishability. Reichenbach [24] p.8, also favors this view.
36. An element in a global percept, that will be generalized to an object, is an intuitively clear but very complex entity. It is beyond the scope of this inquiry to discuss how elements in two percepts could be identified.

an operation of exclusion (separateness) and is sufficient to define this separateness. Separateness is defined individually for each object identified and is what I call object-time. An object and its time are complementary notions since they are defined by the same process[37]. With objects of perception defined, a (mental) evolutionary system can be hypothesized so that each step represents an equivalence identified in the preceding stage; first objects are identified (objectification), then categories of similar objects are recognized (categorization), then the equivalence underlying a category is recognized (protoconceptualization), then the equivalence forming a category is defined (conceptualization)[38]. A definition of a category's equivalence is a weighted collection of attributes, with an attribute being defined as a special type of maximal category[39]. Recognition of the equivalence underlying a category is the same as recognizing a category's existence independent of its members; definition of the category's equivalence is the same as specifying the category independent of its members[40]. Protoconcepts cannot be manipulated independent of physical objects. Since the equivalence underlying a category is recognized but not specified, only a member of that category (that demonstrates the equivalence) can represent it[41]. A concept is free of physical objects since the equivalence of the category is specified and can be re-created in many forms[42]. An evolutionary advantage of conceptualization is the ability to manipulate categories of objects (through their concepts) without manipulating the physical objects that compose them.

Because objects and time are complementary, the evolutionary hierarchy for objects suggests a concomitant hierarchy for time. Object-times, concomitant with objects, are related to durations[43] and characterize the rates of change in the global percepts[44]. Given the collection of object-times

37. Another way of stating this is that identifying elements in separate global percepts gives the element persistence which 'simultaneously' defines object and object-time.
38. See Hartman [25] p.220-271 for some arguments against an Aristotelian analysis of objects and concepts. The present system does not require an externally fixed set of concepts to discover and, therefore, Hartman's objections are not transferable to this account. In addition, the present formulation provides a continuity between concepts and pre-conceptual stages thus avoiding the eristic paradox.
39. Subcategories can be recognized as similarities in separate object categories - for example recognition of a similarity in horse and dog categories leads to recognition of a subcategory of tail. Subcategorization is identical to recognition of fine detail and the more basic a detail, the larger is its equivalence class (e.g., the equivalence class of 'tail' contains all object categories that have a tail). A threshold is reached when enough fine detail is recognized to unambiguously specify the equivalence of routinely encountered object categories. The special recognized categories that uniquely decompose these object categories I call attributes. A definition of a category's equivalence is a weighted collection of attributes. For more on these topics, see [26] and [27].
40. This process is the same as recognizing or specifying that there is a 'tree-ness' that is common to all trees, but exists apart from any particular tree. It is the equivalence relation underlying the category of trees. The equivalence is not known, nor does it exist, *a priori* but is created as a product of increasing mental capacity.
41. The appearance of protoconceptualization in mental evolution would be identified by the isolation or display of unaltered natural objects, indicating that a member of a category is being used to represent the equivalence underlying that category. Exactly such artifacts are first found in the Middle Paleolithic Age as products of Neanderthal man, i.e., burial and 'ritual' sites. See [26].
42. In modern conscious man, concepts exist in an abstract mental space. Other, physical forms of conceptualization are possible, however, and can be identified in Upper Paleolithic Age artifacts. For example, the animal statuettes that first appear in this era are *prima facie* evidence of conceptualization, by this definition, since they must contain adequate attributes to define an animal category if they are recognizable. These topics are discussed in [26].
43. The duration of object-times is not metaphysically independent of objects, nor is it metaphysically subordinate to objects, it is complementary.
44. Intuitively, object-time is a ratio of the physiological interval separating global percepts and the degree of change of the object between successive percepts — the faster something changes, the shorter its fundamental duration measured by object-time. An object-time is relative and the standard of reference is that of the perceiver, i.e., the object-time of the object 'me'.

(categorization), a further equivalence can be recognized. Recognition of the equivalence of object-times results in what I will call uniform time, concomitant with protoconcepts. That is, uniform time is the recognized nature common to all object-times, and independent of any object-time. It is the common time in which all objects are embedded, but it cannot be manipulated separately from these objects. Uniform time is relational, but not measurable, and is a rudimentary B-series[45]. There is an additional equivalence in the hierarchy of time giving rise to conceptual time. Concomitant with concepts, concept-time is the time of conceptual relations[46]. Conceptual time allows a separable standard duration that can be measured through the concept of number (see note 45). Conceptual time is characterized by a measurable relational structure of events, i.e., before and after, but does not include the *nunc fluens*. In other words, conceptual time is McTaggart's B-series[47].

There is a privileged category in both object and time sequences that consist of a single object and object-time — the physical body of an individual and its object-time. The category of the object, 'me', is generalized to the protoconcept, proto-I, and the concept, (the subject) I[48]. This sequence applied to the object-time of 'me' gives rise to a *nunc fluens*. This A-series is not universal, rather it is the time of the personal existence, i.e., the time of the concept I. This I-time is the conceptual member of the specific temporal sequence concomitant with me, proto-I, I.

The object-time complementary to the object, me, forms a privileged category with a single member, as does the object category. This object-time provides an unmeasurable standard duration (see note 44). In uniform time, the proto-I is embedded in its B-series of events which forms the life history of the individual. The concept, I, is the locus of direct experience perceived as separate from, but centered in the body. The I-time is the time of this experience, that is, the experiential aspects of the life history as experienced by, I. Since direct experience is of the perpetual now, I-time is of the flowing now, i.e., a personal A-series.

CONCLUSION

Since ancient Greece, philosophers have been faced with the problem of reconciling seemingly incompatible ideas about time such as the ever-changing structure of events as past, present, and future, and a fixed relational structure of before and after. In addition, there is the metaphysical independence from sensible objects needed for the time of universal physical laws. By viewing the natural philosophy of temporality from an ontological perspective, it has been necessary to exclude A-series time, and merge B-series time and duration. The present development suggests how these characteristics of temporality can be retained and unified.

By extending the relation of sensible objects and concepts to the formation of objects from undifferentiated global percepts, objects and time

45. Measurement requires the concept of number. The protoconcept of a number is a recognized equivalence of categories with equal cardinality, but since it is not defined, it cannot be separately applied for quantification.
46. A conceptual copy of the perceived world is possible wherein each individual object is represented by its concept (i.e., the specification of the category that consists of only that object). Conceptual time is most simply viewed as the B-series time of this duplicate world.
47. Conceptual time is internally derived and therefore individual, yet since it is measurable, it can be externalized by the creation of clocks and physical theories. It is the unambiguous correlation between individuals of this externalization that gives conceptual time its existence independent of any individual. This is the origin of the universal character of McTaggart's B-series time.
48. The protoconcept, or concept, of the single-element category of an individual is the defining characteristics of that individual, just as a protoconcept or concept of the category of horses is the defining characteristics of horses. The proto-I and I exist independently of the object, i.e., independent of the physical body of the individual. Similar to all protoconcepts and concepts, the category gains an existence independent of any member of the category it generalizes. The difference between proto-I and I is only important in this development for the concomitant types of time. It does have archaeologic significance, however. See [26].

are seen as rigorously complementary. It is then possible to hypothesize a more detailed hierarchy of mental evolution in which different types of time are obtained through a concomitant series.

The present definitions of characteristics of time differ from previous formulations in two important ways. First, time as duration is not independent of the perceptible universe as in pre-Aristotelian philosophy and post-Newtonian physical theories, nor is it dependent on the objects of perception as in Aristotle, but rather time and objects are complementary. Second, A-series time cannot be universally defined — not because relativity won't allow it, but because it is not possible to define an equivalence of the experience of time between individuals[49]. Thus, the A-series time defined epistemologically is not McTaggart's, though it retains all of his characteristics but universality.

Three fundamental aspects of time are duration, B-series time, and A-series time. In the present analysis these three unique attributes arise in a simple hierarchical sequence. Object-time (duration) arising complementarily to objects, uniform time (B-series) arising from recognizing the equivalence of object-times, and conceptual time (measurable B-series) arising by defining that equivalence. When applied to the privileged category consisting of a single object (the physical body) the conceptual I-time is seen to represent the temporality of experience - the *nunc fluens* and a personal A-series.

CONFLICT OF INTEREST STATEMENT

There are no conflicts of interest.

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49. McTaggart's A-series is the commonalty of the experience of time existing independent of any particular personal experience of time. That is, it is the equivalence relation underlying the category of all personal A-series. However, since there is no communal mind in which such a category can exist, McTaggart's A-series is impossible at the present stage of mental evolution.

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