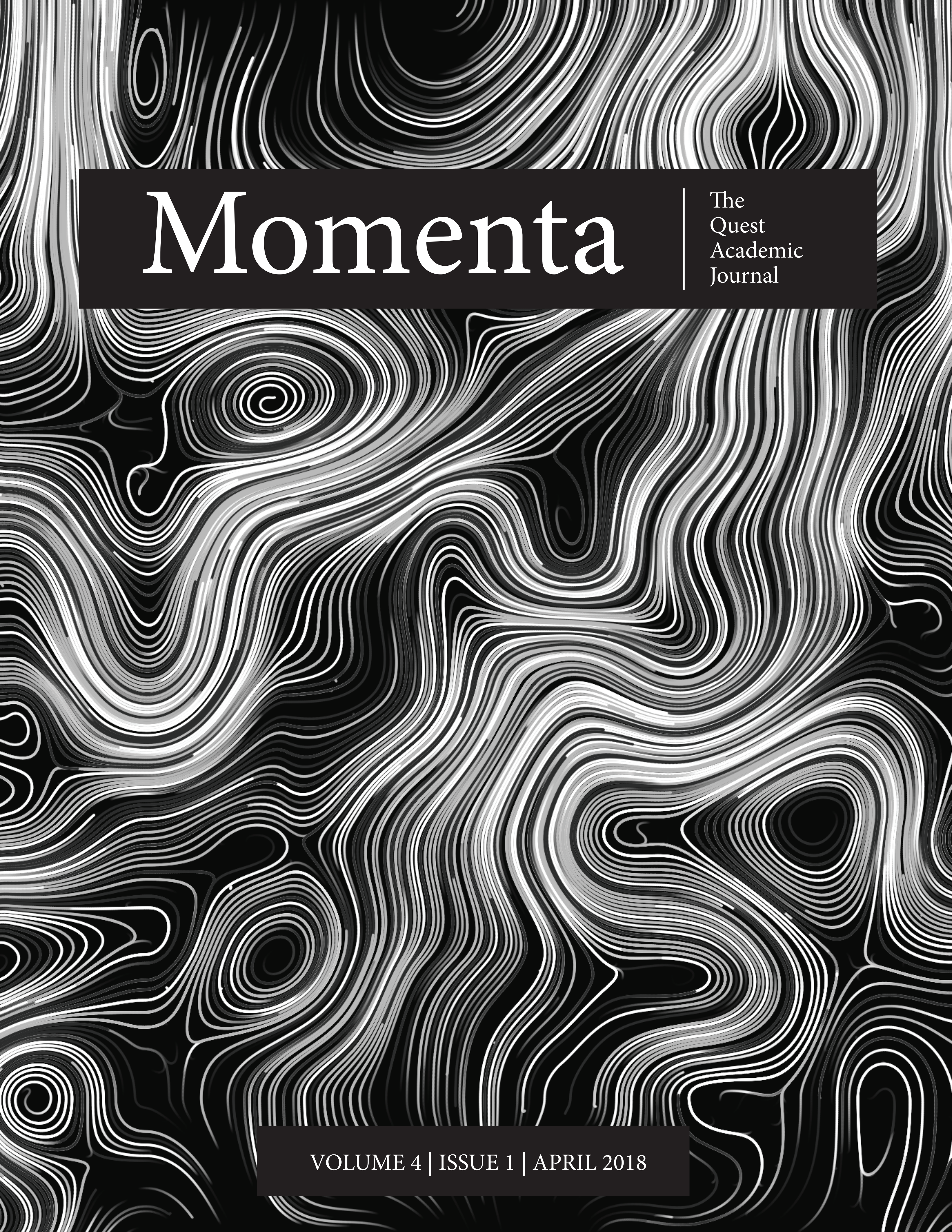

Momenta

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On the cover

Perlin Noise developed by Ken Perlin in 1983.

Perlin developed an algorithm that generated more realistic textures for computer graphics by creating noise that more accurately depicts the "randomness" seen in the natural world. Perlin noise gives graphical engineers and artists the ability to generate organic geometries with a computer. We chose this image for the cover to reflect on how we, humans, interpret and perceive the complexity of the world around us.

momenta (n. pl.) Latin

1. The indwelling forces that are the principle of change.

2. The circumstances that precipitate change.

The papers in this volume are momenta in the sense

[ii] that they are reactions to a set of circumstances (the ideas, the work of understanding, the opportunity to consider those ideas), and also in the sense

[i] that they make contribution to ongoing scholarly discussions and so inevitably change the course of those discussions.

Translated by Darcy Otto, Professor of Philosophy and Classics at Quest University Canada

ACKNOWLEDGEMENTS

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FOREWORDS

There is some kind of magic in seeing a great idea come to life. Even more so when it keeps happening! The Journal you hold is the fourth since our first publication in April 2015. As with all magic, rare ingredients and peculiar preparations were necessary; of which we can officially disclose three.

First, you need extraordinary tutors. For even though they might have and probably do have extraordinary schedules, some will still set time aside to endorse or nominate exemplary papers.

Second, find thorough and passionate students. Find the students willing and capable of nurturing their interests or pursuing that contradiction or sitting with that hint of a creative short story. These must be the kinds of students that work far past their first draft undaunted by reading their paper again or examining another round of constructive criticism.

Third, do not forget the critics. Of all secret ingredients of magic, you must have the bitter bark. Yet the student that volunteer to peer review our submissions are far from bitter people. Rather, they are careful thinkers. They collect our confusions, inconstancies, and fallacies and hold us response-able.

Off the record, the beating heart of this magic is yet again, more students; students who joined or founded the editorial board over the past four years. Though most of us graduate and others go on exchange at the end of this year, the next year's editorial board has our utmost confidence.

Without further ado, prepare yourself for some Quest magic.

Yours,

Ísabella Thorsteinsdóttir
Arlette Akingeneye
Lauren Bauman
Johannes Bodendorfer
龍沐夏 (Akasha Long)

I am pleased and honoured to contribute a few words to this fine journal.

I arrived at this village of people, individuals from around the world, last September. What a joy it has been to meet you. I feel a privilege as you welcome me into your world. Your stories inspire me, they challenge me, they move me. Your ideas are stimulating. Your circumstances make me ponder matters, both light and bright, as well as dark and sad. You are unique. Your colours on the palette contribute, change, transform. As the colours meet each other I find the emerging tones and hues beautiful.

I admire your industry. I watch the learning that happens as a result of your interactions. I see the guiding hand of tutors who can illuminate a path walked before. The practice of research, or writing, of logic and existing knowledge are all elements in the life of learning in this village. The dynamic morphing of tutor to student, and student to teacher, tumble along time and define this Quest.

How I treasure these circumstances that feed the life in our community. Movement and change mark a vibrant life. Your curiosity and active lives are forces that move us forward. Your papers here reflect research and scholarly efforts of the highest caliber. They are evidence of much work, of dedication, and of relationships with peers and teachers. Your contributions transform knowledge.

Thank you for your hard work. I encourage you to keep moving, seeking and changing our world for the better. I challenge you to acknowledge and be curious about other ways of knowing, of Traditional Knowledge, and the wisdom held by those who have come to their truths by their experiences outside the walls of the academy. Momenta presents boundless potential in being an agent of change, leading us all to the next new vista over the rise before us.

Congratulations on another excellent issue,

George Iwama
President and Vice-Chancellor
Quest University

Snail Shell Colour Evolution Can Determine the Fate of the Daisyworld Parable

Valerie Fowles

Introduction to the Simulation

The Daisyworld parable is a computer simulation designed by James Lovelock to illustrate the plausibility of the Gaia hypothesis, which proposes that living organisms interact with their inorganic surroundings to form a complex, synergistic, self-regulating system that maintains the conditions for life on earth (1)(2). The key problem with the simulation, which will be addressed throughout this paper, is the incompatibility of a simplified model of genetic adaptation and the complexities of genetic resilience on earth in response to environmental stimuli. An in-vitro experiment will be done to demonstrate this incompatibility tangibly, and to prove that rapid organism adaptation in response to environmental stimuli is plausible. Current renditions of Daisyworld provide useful predictions of how Earth's biosphere may respond to anthropogenic interference. The outcome of the proposed experiment will provide insight on the additional complexities of earth systems and allow scientists to tweak the model accordingly. The importance of having an accurate model of earth systems has never been greater, as the threat of dangerous climate change looms and we remain ignorant to our effects on the global climate.

Daisyworld is a cloudless planet with a negligible atmosphere on which only black and white daisies grow, and radiation from a nearby star becomes increasingly intense. One could imagine the colour difference with respect to albedo levels: one species is darker than bare ground and consequently absorbs more light, one species is lighter than bare ground and therefore reflects more light (1). Lovelock hypothesized certain circumstances that were to occur on Daisyworld as radiation levels increased.

- The hotter the planet gets; the more white daisies will thrive due to their increased ability to reflect heat, preventing overheating
- The higher the population of white daisies, the more heat is reflected and the lower the planetary temperature
- The cooler the planet gets, the blacker daisies will thrive due to their increased ability to absorb heat, preventing freezing
- The higher the population of black daisies, the more heat is absorbed by the planet and the higher the planetary temperature

Under these circumstances, the system exhibits a stable point around which the daisies can successfully homeostat the temperature over a wide range of radiation levels (Figure 1). By simplifying the earth's biosphere enormously in the form of Daisyworld, the simulation can be described in terms of a few equations borrowed directly from population ecology theory (3) (see appendices). Although the math involved will not be discussed in this paper (see appendices), it is imperative for the reader to know that the Daisyworld equations form a system of non-linear, multiple feedback loops, demonstrating that climatic and population steady state can in fact be achieved simultaneously (1)(2)(4).

The Daisyworld simulation adequately demonstrates the effect of temperature changes on natural selection as well as the effects of biological albedo on temperature. Additionally, while not explicitly concluded in Lovelock's paper, Daisyworld demonstrates the resilience of ecosystems under extreme conditions, and the tendency of ecosystems to strive for stasis (2). What Daisyworld fails to demonstrate is the dynamicity of single living organisms and populations. It operates under the assumption that organisms and organism populations grow, adapt, and die at constant rates and independently of one another when this is simply not the case. Organisms are dynamic beings at the individual and population level in that they can respond to stimulation, not only from their abiotic environment, but also the biotic stressors that come from living in close proximity to other dynamic beings. Density-dependent ecological processes such as birth rates and death rates increase and decrease at inconsistent rates as populations grow and shrink (5). Inter- and intra-species competition – which have equal weighting on Daisyworld – are variable (6)(7). For example, inter-species competition can be stronger due to allelopathy – the secretion of inhibitory chemicals that interfere with the growth and reproduction of other plants (8).

In addition to the listed variables, adaptive variation, particularly colour change, could play a role in altering the Daisyworld simulation. Adaptive variation occurs in species on earth when new environmental niches and their subsequent challenges are made available. For example, an increase in solar radiation results in a hotter and brighter world. What must be tested is the plausibility that the lightening or darkening of an organism's exterior would occur because of rising temperatures. The addition of these hypothetical variables could alter the results of Daisyworld (Figure 1), including when stasis is achieved, if ever (2). If it is confirmed that populations can adapt (their colour) rapidly in response to temperatures rising, the original Daisyworld model proposed by James Lovelock can no longer claim to represent the climate's effect on biota, as daisy populations may not grow and die in response to the increasing solar radiation, but change colour over multiple generations to ensure the survival of their population (2)(4).

The Effects of Temperature Changes on Adaptive Variation

It has been found that for a major evolutionary change to occur and accumulate in complex organisms, it takes about one million years (13)(14). Over the past 50 years, the average global temperature has increased at the fastest rate in recorded history (11)(12). With rapid and drastic global temperature changes occurring, organisms no longer have the luxury of slow evolution. To survive, they must adapt.

On Daisyworld, the daisies don't have this ability. Without any mechanisms for adaptive variation they simply die when it gets too hot or cold (1)(2). I find this an unrealistic portrayal of the resilience of living organisms when faced with extreme conditions. There have been many studies on organisms' ability to evolve under extremely fast evolutionary pressure caused by rapid variations in local climate, including drastic temperature changes (15)(16)(17)(18)(19)(20). In short, the Daisyworld simulation does not account for rapid organismal adaptation which very much occurs on earth. It therefore cannot accurately simulate a planetary system. Of the studies done to examine rapid phenotypic evolution in response to climate change, snails have stood out as favoured candidates for exploring this phenomenon further. A study on the influence of climate change on snail shell colour suggests specifically that living organisms are capable of rapidly adapting their *colour* to mitigate the effects of increasing temperatures (21).

Cepaea Nemoralis

Cepaea nemoralis is a species of land snail that plays a crucial role in ecological genetics because its outward colour and banding phenotype is entirely genetically determined, as opposed to environmentally determined. *Cepaea nemoralis* is also highly studied because of its wide genotypic variation. Studies on the classic shell colour and banding polymorphism of the snail demonstrate the importance of natural selection in maintaining morphological variation (22)(23). It has been observed that banding and colour alleles have co-adapted (e.g. yellow and banded, pink and unbanded) because of habitat and have strong genetic "linkage" that prevents them from mutating and recombining (24)(25)(26). This brings the influence of climate change on genetic composition into question. Does the climate have so large an influence to alter the very building blocks of an organism?

Researchers Małgorzata Ozgo and Menno Schilthuizen think so. They claim their study is "among the first to detect consistent evolutionary change attributable to global climatic warming in *C. nemoralis*" (21). They compared shell colour forms in the land snail at 16 sites in a 7x8 km section of the Province of Groningen, the Netherlands, between 1967 and 2010. They hypothesized that shell colour and banding pattern in *Cepaea* jointly affect the snails' thermoregulation, with lighter shells at an advantage under hot and exposed conditions. The snails would therefore evolve to be lighter overtime as the temperature rose between 1967 and 2010, which their results confirmed. However, their study also explores evolutionary change in various phenotypes due to population bottlenecks and habitat change (21). The results of this portion of the experiment were inconclusive. However, the argument for the role of rising temperatures in phenotypic and genotypic variation could be solidified with an experiment where all other variables are eliminated. I propose an in vivo experiment in the lab wherein variables such as radiation levels, temperature, humidity, and population can be regulated, and other variables associated with natural habitats eliminated. Only phenotypic variation will be considered in this experiment, but genotypic variation could be further explored in a separate experiment to determine the exact mutations of the genes determining shell colour (21).

Proposed Experiment

32 snails, *n*=8 per tank, will be obtained and distributed randomly among four 1-gallon tanks. The tanks will be equipped identically with the necessary products needed to create a snail habitat, to eliminate as much as possible habitational variables such as available food sources, stimulation, and water sources that may affect the outcome of the experiment. The bottom of each tank will be lined with an identical depth of calcium-rich, low-acidity, peat-free potting soil: ~2 inches for adequate burrowing opportunity (30). A shallow water dish, such as a resin reptile dish, will be placed in each tank to provide the tank moisture and drinking water for the snails (31). A hygrometer will be essential for maintaining a consistent moisture level in each tank, 75-90% relative humidity is ideal (32). Three tanks will be equipped with Daylight Basking Spot Lamps, meant to imitate the sun's heat and visible light without the damaging radiation. One tank will be equipped with a 25W bulb, another with a 100W bulb, and the last with a 150W bulb. The tanks and snails will be subsequently heated to around 23°C, 27°C, and 29°C respectively (33). *C. nemoralis* thrive in temperatures between 20°C, and 30°C (30). The remaining tank will serve as a control. The snails will only be exposed to room lighting and temperatures (~20°C). Snails will be fed fresh fruits and vegetables once every three days (31).

Cepaea nemoralis reach sexual maturity in 1 to 2 weeks, meaning a total of 52-104 generations of snails within a two-year period. The breeding interval of *Cepaea nemoralis* runs from April through October. The number of offspring per brood is around 23 (30). To prevent overpopulation in each tank, 50% of baby snails will be removed from the experiment, the other 50% will remain in their tank of birth. Using a PCE Instruments RGB colour meter, the shell colour of each snail can be quantified and located on a colour spectrum and graphed (36). Additional photos and notes on shell colour and number of bands will be taken every week to record any trends that may occur in response to temperature variation.

Expected Results, Limitations, and Implications

Snails exposed to the highest radiation and heat levels are expected to evolve to obtain the lightest colour shells. It is also expected that the highest radiation and heat levels will result in faster evolution due to more selective pressure; the need to regulate body temperature becomes more dire in more intense environments. The effects of solar ultraviolet radiation are excluded and could be considered in further studies. UV radiation is known to cause distinct gene mutations and further research on genotypic variation in the Daisyworld simulation could be influenced or even impeded by the unpredictable nature of UV genetic mutation (40).

One limitation will necessarily be the deleterious effects of inbreeding on invertebrate DNA (34)(35). It is possible that interbreeding of only 8 snails and their offspring will incur mutations independent of selective pressures like bottleneck situations. These will be challenging to pinpoint. The few studies on invertebrate inbreeding, which have yet to be explained genetically, have shown that morphological traits are minimally affected by inbreeding. However, the fecundity and growth rate of populations diminish greatly with each inbred generation (35).

If snails are found to evolve lighter shells as temperatures rise, the experiment will prove the ability of species to undergo adaptive variation as a result of temperature and climate change. Consequently, the Daisyworld simulation, which portrays an adaptively static population, could not accurately portray the climate's effect on biota, contrary to what the authors claim. Among with inter- and intra-species competition, and density-dependent ecological responses, both of which Lovelock addressed in a follow up paper (2), adaptive variation proves to be another reason why Daisyworld is far from an impeccable model for the relationship between the biosphere and the atmosphere. Species are currently facing drastic climate changes and it will only get worse. It's important to consider more complex simulations to be able to model and understand how resulting adaptation to these changes will affect the equilibrium potential between terrestrial life and environment.

Figure

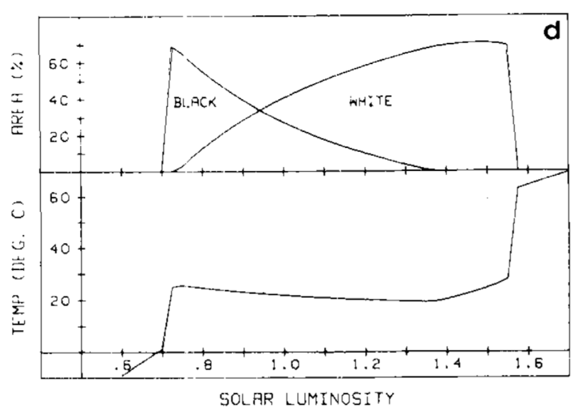

Figure 1. Illustrates the behaviour of the Daisyworld model. As radiation levels increase, black daisy populations decrease and white daisy populations increase due to their ability to reflect radiation and therefore maintain a cooler internal temperature (top section). The growth and shrinkage of the juxtaposing daisy populations serves to stabilize the temperatures on Daisyworld as radiation levels increase. Because of the albedo effect of white daisies, the daisy ecosystem can successfully homeostat the temperature over a wide range of radiation levels (bottom section).

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Appendices

I. Temperature: The temperature of Daisyworld is calculated using some very basic equations, starting with the *Stefan-Boltzmann Law*, which states that the rate of energy given off through radiation by an object is proportional to the fourth power of the object's temperature and is described in the following equation:

$$F = \varepsilon\sigma A T^4$$

where F is the rate of energy flow in Joules/sec (or Watts),
ε is the emissivity of the object, σ is the Stefan-Boltzmann constant, A is the surface area of the object, and T is the temperature of the object in degrees Kelvin. The Stefan-Boltzmann constant has a value of 5.67E-8 Joules/sec m^2 K^4. The emissivity is a dimensionless number and ranges from 0 to 1; a perfect black body has an emissivity of 1, while very shiny objects have an emissivity of close to 0.

II. Planetary Albedo: The albedo of Daisyworld is a function of how much of its area is covered by white and black daisies. The albedo of uncovered land is set to 0.5, the land covered by white daisies has an albedo of 0.75, and the land covered by black daisies has an albedo of 0.25. The planetary albedo is calculated in the following manner:

$$A_{planet} = f_{un}A_{un} + f_w A_w + f_b A_b$$

where A is the albedo and f is the fraction of the total area of the planet covered or uncovered by different materials.

III. Daisy Growth: Each daisy population has a preferred temperature range and will grow best at an optimum temperature within an upper and lower temperature limit. The model incorporates a growth factor that varies from 1 to 0, defined according the following equation:

$$\text{Growth Factor}_{white} = 1 - 0.003265(22.5 - T_{white})^2$$

The growth factor for the black daisies is calculated in a similar manner

IV. Local temperature: The local temperature of the land around the two types of daisies will differ because they absorb different amounts of solar energy. The black daisies absorb more energy and they radiate this energy, heating their surroundings. In contrast, the white daisies reflect more solar energy, which lessens the amount absorbed in that region, cooling their surroundings. The local temperature is defined according to the following equation:

$$T_{white} = F_{HA} * (A_{planet} - A_{white}) + T_{planet}$$

where A represents the albedo and F_{HA} is the heat absorption factor (41).

Episodic Memory and Autonoetic Consciousness: A Sense of Self Through Time

Bryn Koehn, Anya Kazanjian, Satori Clarke, Lisa Stewart

Introduction

The field of cognition addresses some of life's big questions: "how do brains develop and function?", "what makes us uniquely human?", and "how do we remember ourselves?". The answers to these questions are a subject of much debate and depend on fundamental assumptions regarding the cognitive processes of the brain. There are four major approaches to understanding these processes: strong nativism, weak nativism, empiricism, and embodied cognition (See "Appendix A" for further explanation).[1] Each theory has implications for memory—the neurocognitive system that enables humans to remember facts, events, skills, tasks, experiences, and concepts. One system of long-term memory that is functionally different from other kinds of memory is episodic memory, or the recollection of past events (1). Research on episodic memory contributes to our understanding of practical areas such as learning, (2, 3), cognitive modeling, memory loss (4, 5), and Post-Traumatic Stress Disorder (6).

In this paper, we will explore the properties and evolution of episodic memory. First, we will review relevant literature on this topic, then we will state our position amongst the four theories and discuss significant implications of our position. We assert that episodic memory evolved from semantic memory due to the adaptive benefits of autonoesis, which enables humans to trust their memories and plan for the future. This view fits best with weak nativism, which asserts that humans are born with innate memory structures.

Literature Review

Definitions of Key Terms

There are two approaches to defining episodic memory. The first is concerned with the content of memory: the what, when, and where of a past experience (Tulving's WWW definition) (1). However, the WWW definition does not adequately distinguish between episodic and semantic memory[2] as a substantial body of empirical evidence indicates that semantic and episodic memory both contain WWW information (7, 8, 9, 10). Further, the WWW definition fails to account for the first-person subjective experience of remembering. That is, individuals may remember the what-when-where of an experience without re-experiencing the event, and vice versa (11). In light of these issues, another definition of episodic memory was proposed.

Tulving (12) incorporated the concepts of anoetic, noetic, and autonoetic consciousness into his theory on memory systems, asserting that the essential distinction between semantic and episodic memory is autonoetic consciousness. Anoetic consciousness refers to a state of awareness that is temporally and spatially bound to the present. Noetic consciousness involves awareness of information and factual knowledge, which is linked to semantic memory and facilitates the ability to utilize information obtained from the past (13, 14). Autonoetic consciousness, also known as autonoesis, involves the subjective experience of the self; it is connected to episodic memory as it enables individuals to recollect and mentally re-experience past events (12, 13, 15). Autonoetic consciousness also facilitates interpretation of the present and self-projection (16), which refers to the ability to "shift perspective from the immediate present to alternative perspectives", like imagining ourselves in future situations (17). In summary, Tulving asserts that the essential distinction between semantic and episodic memory is autonoetic consciousness. Some view WWW, autonoesis, and language as properties of episodic memory, while we concede with those who assert that episodic memory and autonoesis are inextricably linked.

The limitation of using autonoetic consciousness as the distinctive feature of episodic memory is determining an objective method with which to evaluate the subjective nature of remembering (for review of methodological limitations see 18). Thus far, reportability has enabled the study of human episodic memory, but limited the evaluation of nonverbal animals who cannot communicate the first-person experience of remembering (11).

Episodic-Like Memory in Nonverbal Animals

Despite the difficulty of evaluating episodic autonoetic memory in nonverbal animals, some researchers interpret the empirical

1 While these theories provide useful insights on episodic autonoetic memory, they are not the focus of this paper.

2 Semantic memory differs from episodic memory in that it is not linked to any one event or experience. Semantic memory refers to the recollection of factual information (1).

evidence to indicate 'episodic-like' memory in animals, which influences our understanding of how episodic autonoetic memory evolved (19). Researchers posit that homologous structures in human and animal memory systems can be used to deduce that animals have episodic memory (20, 21, 22, 23, 24). Because the hippocampal declarative memory system encompasses both semantic and episodic memory in humans, Squire (24, 25) postulates that the presence of the hippocampal declarative memory system in animals like rats and monkeys suggests that these animals have episodic memory. Researchers have also utilized the three different properties of episodic memory to argue that if animals have one or more of the properties, they have episodic-like memory. The primary property that has been used to demonstrate episodic-like memory is retention of WWW information (26, 27, 28, 29, 30, 31, 32, 33). Western Scrub Jays, for instance, integrate WWW information in their food caching behaviors, remembering what food was stored, as well as where and when it was stored (34). Despite the interpretation of this evidence, contention remains regarding the extent to which animals exhibit episodic-like memory.

There are four primary critiques of the argument for episodic-like memory in animals, namely, non-empirical reasoning, flawed methodologies, inadequate evaluation of temporal knowledge, and unqualified assumptions about subjective mental experiences. First, theory-based postulations subsume episodic memory within semantic memory, without treating the two separately (e.g. 24). Second, empirical methods fail to accurately distinguish between semantic and episodic memory (35). Third, typical tasks used to assess content criterion (the WWW) neglect to account for the subjective experience of self in temporal knowledge (35, 36). The exception to this critique is the experiment involving Western Scrub Jays (34), which demonstrates temporal recollection of food caching. Finally, it is misguided to assume that memory-based behavior in nonverbal animals is indicative of a certain type of mental experience: autonoetic consciousness (11, 35, 37, 38, 39). The ongoing debate over the presence of episodic memory in nonverbal animals has implications for theories regarding the temporal and functional evolution of episodic memory.

Evolution of Episodic Autonoetic Memory

There are multiple theories regarding how and when episodic memory evolved. One theory suggests that episodic memory emerged before mammals and reptiles diverged (40). That is, core properties of episodic memory are evident in other non-human species because of a shared "neural ancestry". Conway (41) concurs that episodic memory is not uniquely human, postulating that human episodic memory is just more developed than that of other animals. Another theory conjectures that episodic memory developed within the *Homo sapien* lineage. In other words, semantic memory was shared among species but *Homo sapiens* were unique in developing episodic memory (14, 35, 39). Whereas theories concerning the temporal evolution of episodic memory primarily focus on the development of episodic memory itself, theories concerning the function of episodic memory tend to hypothesize about the adaptive benefits of autonoetic consciousness.

Relevant literature suggests that theories converge on the adaptive benefits of self-projection, implying that *Homo sapiens* may have developed autonoetic consciousness through natural selection. To review, autonoesis involves the subjective first-person experience of remembering, interpretation of the present, and future-oriented thinking. It allows for self-projection, which enables one to see themselves in situations other than the present. Self-projection increases an individual's likelihood for survival as it improves one's flexibility in novel situations and allows for long-term, goal-oriented planning (7, 11, 35, 38, 41, 42, 43, 44, 45, 46). Conway (41) asserts that autonoetic consciousness is unique to humans, and enables a continuous sense of self, or self-image. Klein (7) counters that there is no empirical evidence to support this claim. Instead, Klein asserts that autonoesis evolved through natural selection, allowing humans to trust their memories, which improves the speed and efficacy of future-oriented responses. If, for example, humans had to analyze the content of their memories to determine whether they are accurate representations of reality, they would lose valuable time (7). Similarly, Tulving (35) asserts that future-oriented thinking is the primary reason for autonoesis and distinguishes humans from all other animals.

Position on the Literature

Definitions of Key Terms

Thus far, we have reviewed the various definitions of relevant terms like episodic memory and autonoesis, the presence of episodic memory in animals, and the evolution of episodic and autonoetic memory. In order to take a position on the different theories that attempt to explain episodic autonoesis, we, in turn, must define our terms, interpret the evidence, consider the refutations, and discuss the implications. At the beginning of the review, we summarized two definitions of episodic memory. We align with the second, which asserts that autonoesis is an inextricable feature of episodic memory, distinguishing episodic from semantic memory (7, 11, 35, 39). Episodic memory is characterized by its usefulness but not its accuracy; therefore, the accessibility of accurate WWW information is not necessarily indicative of episodic memory (47, 48). With this definition, we can interpret the evidence regarding animals and episodic memory.

Episodic-Like Memory in Nonverbal Animals

Studies have shown that Western Scrub Jays, meadow voles, rats, and nonhuman primates, among others, can recall what-when-where (WWW) information (30, 34, 49, 50). Recollection of WWW information is not indicative of episodic memory, and the limitation of reportability prevents the acquisition of sufficient evidence. Block (51) confronts the same methodological limitation of reportability in regard to consciousness, arguing that reportability is not a prerequisite of this phenomenon, as exemplified by individuals with profound global aphasia[3] who clearly demonstrate phenomenal states through physical, non-

3 According to the National Aphasia Association (52), global aphasia is a neurological condition in which a patient has lost the ability to produce and understand language.

verbal communication. We agree that reportability is a characteristic rather than a prerequisite of autonoetic consciousness, yet we can only definitively say that humans have episodic autonoetic memory.

Evolution of Episodic Autonoetic Memory

If episodic autonoetic memory is uniquely human, then this places constraints on its evolutionary timeline. Considering that episodic and semantic memory share their content criterion, we propose that episodic memory evolved from semantic as autonoesis developed. In congruence, Vandekerckhove, Bulnes and Panksepp (14) argue that at their most primal level, *Homo sapiens* had semantic, noetic consciousness, from which higher levels of consciousness evolved as our brain structures became more complex. This view is also incorporated into Tulving's theory of declarative memory (35, 39).

Studies in developmental cognition support our position that episodic memory developed from semantic memory. In examining the phenomenon of childhood amnesia, Scarf, Gross, Colombo and Hayne (3) demonstrate that children under the age of four are incapable of remembering important past events. These participants could only express semantic knowledge. They claim that the emergence of episodic memory is the end of childhood amnesia, when four year olds begin to retain personal memories for an extended period of time. Burns, Russell and Russell (2) reaffirm Scarf et al. (3) by demonstrating the same results with different experimental methods. Together, these studies indicate that infants develop episodic memory in tandem with the ability to identify the self in memories between the ages of four and seven. On the evolutionary timescale, such evidence corroborates our claim that episodic memory developed after semantic and in synchrony with autonoetic consciousness.

This development occurred through natural selection due to the adaptive benefits of episodic autonoetic memory. We concur with the proposition that autonoesis enables confidence in one's memories (7) and facilitates self-projection (35). Re-experiencing our memories helps to differentiate between the content of memories and that of our thoughts or imaginings. Further, the self-reflective manner of recollection allows us to comprehend that these mental representations are tied to our past. Re-experiencing memories enables trust in the events we recall, allowing us to draw on past information for self-projection. Such long-term, goal-oriented thinking enables us to manipulate our environment to better suit our needs (35). Together, the ability to trust in our memories and self-project provides compelling accounts for why episodic autonoetic memory evolved in *Homo sapiens.*

Implications of Our Position

In light of our position on the theories reviewed, we will now consider the implications of our stance. Through deductive reasoning, we argue that our view of episodic autonoetic memory fits best with a weak nativist approach, as opposed to an embodied, empiricist, or strong nativist approach (see Appendix A). Representations of past events are essential to re-experiencing memories, which negates an embodied perspective. Empiricists postulate that a general learning mechanism accounts for the development of episodic autonoetic memory. An empiricist may assert that the ability to subjectively experience ourselves in memory develops after we learn to form mental representations of ourselves. While this explanation is plausible, an innate memory structure may better account for the early semantic memory of children. With this in mind, we turn to nativism.

Weak nativism proposes that children have qualitatively different brains than adults. While Spelke (53) asserts that language, as a mechanism, transforms young, "alien" minds into more adult minds, we postulate that this mechanism of change may have constituent parts, one of which could be episodic autonoetic memory. That is, childhood cognition becomes more adult-like when children begin to retrieve memories in the same qualitative way as adults. We propose that the high order functioning of episodic memory develops through the interaction of the low order semantic memory module[4] with autonoetic consciousness. Thus, semantic memory and autonoetic consciousness must have the ability to exchange information in order to produce episodic memory. This connectivity can be accounted for by the weak nativist view, which posits that some modules are discrete, while others are interconnected. In congruence with this argument for the interconnectivity of modules, Suddendorf and Corballis (11) assert that self-projection is a taxing process for the brain that necessitates a diversity of cognitive capacities, requiring modular communication. Dehaene and Naccache (54) provide one way in which these discrete modules could be connected, suggesting the existence of long axons that create a network where modular information can be shared. Strong nativists are unable to account for such interconnectivity as they argue for separate, impenetrable modules. For this reason, strong nativism provides a less compelling account for the complex processes involved in episodic autonoetic memory.

Conclusion

This paper has explored the episodic autonoetic system through comparative, developmental, and evolutionary cognition. We position ourselves amongst the various theories reviewed by asserting that autonoesis is an inherent feature of episodic memory, which distinguishes episodic from semantic memory. Given this definition and the methodological limitation of reportability, we can only state that this system exists in humans. Distinguishing autonoesis as uniquely human informs our theory that episodic autonoesis evolved from semantic memory, after humans diverged from primates. Episodic autonoesis was selected due to its advantageous qualities that allow us to trust the source of our memories and project ourselves into the future. Overall, our po-

4 Weak and strong nativism relies on modular theory, which asserts that the brain is composed of independent parts (i.e. modules) that serve different functions. Weak nativism posits that these modules are connected, while strong nativism claims they are discrete and work independently of one another.

sition is most aligned with a weak nativist approach that relies on interconnected modules capable of such cognitive processes. In order to address the methodological limitation of reportability, future research should be directed towards discerning other properties of episodic autonoetic memory that can be evaluated in other species. Discovery of such properties in conjunction with more precise objective methodologies would contribute to the existing body of knowledge regarding episodic autonoetic memory. This research is applicable to developing treatment technologies for cognitive disorders and mental health diagnoses, as well as advancing cognitive modeling techniques.

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Appendices

Appendix A

Table 1: The following is a brief summation of the four major cognitive theories. Each theory has its own proposition regarding the structure of the brain and the processes of knowledge acquisition.

Embodied	Empiricist	Weak Nativist	Strong Nativist
Cognition depends on bodily interactions with the environment. The brain is a dynamic system with a feedback loop between sensory input and output.	The brain is a general learning mechanism that is a blank slate at birth. Gradual acquisition of knowledge and cognitive ability through experience influences the structure of the brain.	Brain is modular but there are some connections between modules.	Brain is modular without any connection between modules. Skills and abilities are 'hard-wired' at birth.

From Rehabilitation to Incapacitation: A 20th Century Shift in American Penal Philosophy

Anya Kazanjian

Introduction

How should the U.S. criminal justice system punish wrongdoers and prevent crime? This daunting and comprehensive question underpins correctional philosophy and informs the laws and policies of criminal justice. Prior to the 1960s, the dominant correctional theory was one of reform and rehabilitation. Over the course of a decade, from the mid-1960s to the mid-1970s, rehabilitation theory was denounced and replaced by one of incapacitation. In order to understand the rise of mass incarceration, discriminatory sentencing practices, and the contemporary correctional system, we must revisit these theories and their practical implications. I propose that rehabilitation theory and incapacitation theory originate from different political ideologies, and thus possess fundamentally different conceptualizations of human nature, the human capacity for change, and the purpose of government. This paper will explore the differences between rehabilitation and incapacitation theory, why the dominant theory of criminal justice changed, and how that change developed under the Republican and Democratic Administrations of Ronald Reagan and Bill Clinton. I assert that socio-political turmoil and non-empirical research influenced the 20th century shift in correctional thinking, which facilitated harmful and discriminatory practices that increased the rate of imprisonment.

An Overview of the Theories and Their Ideological Roots

The shift from rehabilitation theory to incapacitation theory had significant implications for the criminal justice system because the two theories conceive of punishment differently. Rehabilitation theory states that punishment must rehabilitate offenders to prevent recidivism and protect society. Given this, prison should provide a means for reform to help reintegrate offenders into society (1). Treatment and intervention programs should be used to cultivate individuality, responsibility, and respect for authority (2). This may include counseling, behavior modification, vocational training, or college education programs (3). The rehabilitative ideal asserts that punishment must separate wrongdoers from society, reform them in prison, and provide them with a new direction. In practice, this approach calls for policies that reward good behavior like probation, parole, and indeterminate sentences (2). Probation provides an alternative to imprisonment for offenders that are not a threat to society, parole offers the conditional release of prisoners before their sentence is complete (4), and indeterminate sentences do not specify the length of imprisonment so that well-behaved prisoners can receive shorter sentences (5). In this way, treatment and punishment are individualized to promote self-development and rehabilitation.

While rehabilitation theory aims to reform offenders to protect society, incapacitation theory aims to remove offenders to maintain peace and order. Under incapacitation theory, the purpose of prison is to incapacitate offenders to prevent them from committing future crimes (1). This approach presumes that there are an identifiable number of criminals that can be removed from society; thus, higher incarceration rates are expected to correlate with lower crime rates (6). Incapacitation theory views offenders as irredeemably bad apples; like a contagious disease, they must be identified and isolated to safeguard the public (7). This approach justifies long prison sentences that care little for individual development. Proponents of incapacitation theory call for determinate sentencing, mandatory minimums, and the elimination of probation and parole (8). Determinate sentences set definite prison sentences that are not subject to review (9), while mandatory minimums establish fixed minimum sentences for different crimes (10). These measures work to reduce the discretionary power of judges and imprison offenders with little chance of early release.

Rehabilitation theory and incapacitation theory are essentially at odds with one another, in part because they are rooted in different political ideologies. Rehabilitation theory originates in the modern liberal notion of government assistance in individual improvement. John Dewey's Liberalism and Social Action describes how individuals are capable of self-development through education and training. In order to achieve self-actualization, the government must free members of society from external constraints, such as economic insecurity, and provide a means to sustain and direct them (11). Such notions are reflected in the very definitions of rehabilitation and reform, which depend on the possibility of individual change (1). Treatment and rehabilitation programs seek to reform offenders inside the careral system, while reintegration programs, like halfway houses, seek to support formerly incarcerated individuals beyond the prison walls.

Incapacitation theory draws on conservative views of human nature, the government, and individual rights. In "Of the Original Contract", David Hume asserts that humans are naturally self-interested and inclined to steal from others to benefit themselves (12). Hume's "Of the Origin of Government" states that "it is impossible to keep men…in the paths of justice", and that "this great weakness is incurable". Given this "weakness", the primary purpose of government is to impose justice and preserve order, for "men must…palliate what they cannot cure" (13). Traditional conservatives conceive of humans as imperfect beings that cannot be fixed, which is contrary to the liberal notion of individual development. Incapacitation theory places emphasis on the protection and wellbeing of society, rather than that of the offender. In conservatism, class and community prevail over the individual and individual rights; strong communities are essential to the stability of the nation (14). Atomism, according to Edmund Burke, is simply an incorrect view of society (15). Conservative notions of the imperfect human, the need for order, and the wellbeing of society inform incapacitation theory, and starkly contrast liberalism and rehabilitation theory.

From Rehabilitation to Incapacitation

Prior to the rise of incapacitation theory in the 1960s, the rehabilitative ideal was an influential correctional philosophy for more than a century (16). Rehabilitation theory originated in the mid-1800s and continued through the Progressive Era. The growth of scientific disciplines fueled the belief that professionals can change and control the behavior of prisoners (1). By the 1920s, correctional philosophy was focused on individual treatment and rehabilitation (17). Nearly half of all prisoners in 1923 were serving indeterminate sentences, which encouraged good conduct in prison (2). During the 1950s and the 1960s, there were a series of Supreme Court decisions that sought to expand the rights of the accused (8). Over this course of time, the gradual liberalization of criminal law corresponded to low incarceration rates and the emergence of a new vocabulary. Prisons became known as "correctional institutions" (18), and prisoners were referred to as "inmates" (2). The term "corrections" reflected the perceived purpose of prisons: to reform or "correct" offenders.

The movement against rehabilitation theory began in the mid-1960s, as social turmoil and rising crime rates facilitated the rise of neoconservatism and the rejection of the status quo (19). "Disenchanted welfare liberals" (i.e. the emerging neoconservatives) opposed Lyndon Johnson's Great Society programs and other such measures to eliminate poverty and inequality. Neoconservatives advocated for less government intervention to promote individual responsibility (15). Political campaigns began to push for harsher criminal policies, ridiculing those still in favor of rehabilitation for their ignorance and naivete (19). The movement to "get tough on crime" took off in 1975, leading to major changes in the U.S. penal system and criminal law (20).

Liberal and Conservative Approaches to the Shift in Correctional Philosophy

"Get tough on crime" politics and the rise of the incapacitation theory was, in part, a reaction to the socio-political situation of the 1960s and 1970s. This time in American history was host to the Civil Rights Movement, the Vietnam War, city riots, anti-war protests, the Kent State shootings, the Watergate Scandal, and rising crime rates. The criminal justice system came under scrutiny and was often found to blame for the lack of social order (8).

Liberals and conservatives alike denounced the rehabilitation theory but did so for different reasons. Liberals were concerned that the discretionary power of judges and other state officials was being used to target disadvantaged citizens, such as the poor and members of minority groups. Liberals distrusted the state and government officials, which undermined the promotion of indeterminate sentencing laws (17). James Q. Wilson, a professor of political science, advised liberals to consider "definite terms of incarceration", even if only for short imprisonment sentences to avoid the abuse of discretionary power (8).

Liberals thought that the American penal system victimized offenders, while conservatives thought it victimized society (21). Conservatives condemned liberal laws for indeterminate sentencing, probation, and parole by arguing that these laws prematurely released dangerous offenders into society (17). In short, neither liberals nor conservatives trusted the state. They both sought to reject rehabilitation theory and develop determinate sentencing laws to limit the discretionary power of judges and other correctional officials. Liberals advocated for short prison sentences, in accordance with the liberal assumption of the human capacity to change and improve. Conservatives, on the other hand, advocated for long prison sentences in accordance with the conservative belief that human imperfection is incurable (21).

Liberal and conservative opposition to rehabilition theory was fueled by sociologist Robert Martinson's study titled "What Works?", which provided seemingly scientific grounds for the rejection of the theory. Martinson published a review of 231 studies in 1974 (21). In it, he concluded that the U.S. criminal justice system knew little about how to effectively "rehabilitate offenders and reduce recidivism" (21). Martinson's conclusion spread and became what is known as the "nothing works" doctrine, despite criticisms from other members of the scientific community. Some researchers protested his claims, asserting that fifty percent of the studies Martinson reviewed were found to reduce recidivism. In addition, only 80 of the 231 studies focused on the effects of intervention and treatment programs on recidivism (21). Regardless of these objections, "nothing works" became the mantra of those opposed to the rehabilitative ideal and liberal programs (21, 17, 22). Cullen and Jonson (16), and Phelps (23) claim in their respective articles that liberals and conservatives coalesced around Martinson's farfetched conclusions. The socio-political turmoil and desire for determinate sentencing made it a convenient, albeit inaccurate, message to spread. Rather than consider alternate ways to implement the rehabilitative ideal, rehabilitation was deemed ineffective and abandoned for incapacitation theory, which was significantly advanced by the Reagan Administration.

The Reagan Administration: Punitive Crime Laws and Rising Incarceration Rates

Ronald Reagan was instrumental to the transition from "get tough" rhetoric to "get tough" policy, signifying the definitive shift to incapacitation theory in the criminal justice system. Richard Nixon coined the term "war on drugs" in the 1970s, but Reagan advanced the campaign by promoting the elimination of parole, mandatory minimum sentencing laws, and the construction of more prisons (8). In line with incapacitation theory, mandatory minimums sought to incapacitate criminals and treat all offenders equally under the law. In practice, mandatory minimums restricted judges from considering the influence of circumstance and led to discriminatory practices, for the risk of incarceration was not evenly distributed across society. Mass incarceration enabled the "'systematic imprisonment of whole groups of the population'" (24). The "crack crisis" of the mid-1980s, for example, led to the instatement of different mandatory minimums for crack and cocaine, even though they were different forms of the same drug. The mandatory minimums for crack were far harsher than those for powder cocaine. Crack was cheaper than cocaine and more common in urban areas, thus the mandatory minimum disproportionately targeted black Americans and moved the U.S. into the era of mass incarceration (8).

The introduction of a new sentencing structure in 1987 contributed to the rising rate of incarceration, extending the use of harsh sentencing policies. The federal government proposed "43 levels of crime seriousness", which established uniform sentencing policies that limited the discretionary power of corrections officials and eliminated parole for federal prisoners. This structure was far more complex and cumbersome than any of the sentencing guidelines at the state level (8). For comparison, Minnesota had ten levels of "crime seriousness", while Washington had fourteen, and Oregon had eleven. In accordance with the incapacitation theory, Reagan decreased discretionary power and individual treatment by enacting policies that standardized harsh sentencing laws (8).

<u>The Clinton Administration: Conservative Policies and the 1994 Crime Bill</u>

Like Reagan, Clinton ran his campaign on a platform of law and order, yet his modern liberal values clashed with those of right wing policy groups. The National Rifle Association (NRA), the National Community Pharmacists Association (NCPA), Heritage, and the American Legislative Exchange Council (ALEC), among others, consistently promoted conservative policy reforms and their own political agenda (8). These policy groups developed "truth in sentencing" practices that sought to decrease parole so that more convicts served complete sentences. They also proposed the "three-strikes" law that aimed to increase the length of sentences for those who had previously committed two or more serious crimes (8). In addition, a movement for victims' rights emerged and called for more conservative reforms and the prosecution of violent juvenile offenders as adults (8). In 1991, the NRA founded the NRA Crime Strike to campaign for harsher sentencing and protest the release of inmates on parole (25). The Clinton Administration repeatedly came under attack for being too soft on crime (8). Clinton was criticized for diverting money to fund alternative means of punishment, such as boot camps. Critics claimed that such money could be better spent on prison construction (8).

The struggle between liberals and conservatives over the severity of punishment culminated in the Violent Crime Control and Law Enforcement Act of 1994. This lengthy crime bill was the largest in U.S. history, and a source of much debate. Conservative politicians and policy groups advocated for the inclusion of a three-strikes law that would mandate life in prison for repeat offenders. Conservatives also fought to expand the death penalty and increase funding for prison construction and the employment of more police officers (26). Clinton adopted and incorporated these measures, but also included more liberal policies like gun control and programs for crime prevention (8). The final bill dedicated $6.1 billion dollars to crime prevention, yet the bill was primarily punitive, rather than rehabilitative (26). Clinton, among other liberal politicians and congressman, accepted the movement to "get tough on crime", adopting policy positions that were traditionally more conservative.

<u>The "Tough on Crime" Legacy</u>

The "get tough on crime" politics promoted by the Reagan and Clinton administrations led to discriminatory practices and mass incarceration. From 1970 to 2000, the prison population grew from roughly 357,292 to 2,015,300 (27). The shift from rehabilitation theory to incapacitation theory enabled more severe and uniform sentencing policies that led to a disproportionate number of young black and Latino men behind bars. A 1991 study by Darrell Steffensmeier and Miles D. Harer (28) shows that despite stricter law enforcement and higher rates of incarceration, there was "no discernible reduction in crime rates" under the Reagan Administration. The rate of violent crimes did fall over the course of the Clinton Administration, but a 2005 Government Accountability Office Report concludes that the reduction in crime was primarily due to other factors like increased employment (29). At most, Clinton's policies and the 1994 crime bill accounted for 1.3 percent of the overall decline due to the employment of more police officers (29). The incapacitation theory led to the imprisonment of thousands, yet its actual impact on crime rates was relatively modest.

<u>Conclusion</u>

It is difficult to discern the use and effects of correctional philosophy. It may be impossible to determine the real potential of any correctional theory, but I propose we judge them by their consequences. The shift from rehabilitation theory to incapacitation theory was spurred by socio-political turmoil, non-empirical research, and a general distrust of the government, which were primarily external to the theory itself. The incapacitation theory, on the other hand, has had tangibly negative effects. The rise of severe punishment and mass incarceration are, in part, justified by the theory. We must reconsider the rehabilitative ideal and its various methods of implementation to reduce harmful consequences and maximize fairness and equality under the law.

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Time-Continuous Turing Machines

Lars Š. Laichter

Introduction

What is the mind? Is it a computer? And if so, what is computation?[1] Although Turing machines have been the dominant model of computation[2] , the dynamical account of computation claims to be a better account of computation, including cognition. In the following paper, I offer an outline and a critique of both Turing's and the dynamical account of computation. I argue that a major inadequacy of the Turing model is a lack of a continuous temporal dimension. Subsequently, I propose a series of amendments to the Turing model in the form of a time-continuous Turing machine, which adopts several features from the dynamical account of computation. Using an example of a super-sunflower by Smith (1), I exemplify how the Turing account of computation can be transformed into a more dynamical account of computation and briefly discuss what is at stake when improving our account of computation. Subsequently, I conclude that there is not an incompatibility between having a dynamical description and having a computational description.

What is computation?

I shall first consider the question of what computation is currently understood. In an era where we are surrounded by computing machines, it is easy to fall into a delusion that there exists a 'comprehensive' theory of computation. Smith (2) challenges the idea that there is a 'comprehensive' theory of computation. He proposes three criteria for a potential theory of computation, the *empirical, conceptual* and *cognitive*. These criteria would allow us differentiate computing from other processes. The *empirical* criterion requires a theory of computing to explain the full range of computational practice. The *conceptual* expects the theory of computation to provide an understanding of what computation is, where it comes from, and what properties are sufficient to consider a system a computational system. Finally, the *cognitive* criterion requires a theory of computation to account for its own consequences and implications for the computational theory of mind. Although Smith claims that there will never be a comprehensive theory of computation, I suggest improvements upon our current theories by examining the proclaimed incompatibility between Turing's and the dynamical accounts of computation.

Alan Turing's 'official' definition is arguably the most widely recognised and accepted definitions of computation. In his paper *On Computable Numbers, with an Application to The Entscheidungsproblem*, Turing (3) examines the question of what can be achieved by a mechanism. Turing formulates the conception of a theoretical machine, consisting of an infinite tape, subdivided into discrete squares, and a head that can shift its position along the tape in both directions. The machine can also erase and write characters on the tape, according to a predefined set of instructions. Thus, the conception of computation according to Turing is a discrete symbolic manipulation, altering symbols step-by-step according to predefined table rules. Turing uses this model to prove that there is no solution to the *Entscheidungsproblem*[3] and that the cardinality of the set of computable numbers, numbers computable by finite means, is infinitely smaller than the set of all real numbers $\mathbb{R}$. The Turing machine model is important because it claims to formalize the notion of "effective computability", thereby answering Turing question of what a mechanism can do. By establishing a set of computable functions, the notion of "effective computability" underwrites recursion theory, complexity theory, and the 'official' theory of computation. Similar conclusions were also reached at the same time by Alonzo Church. Thus, the joint conclusions regarding formal systems, independently reached by Church and Turing, are prevailingly known as the *Church-Turing* thesis.

1 This relationship is particularly important in relation to the Computational Theory of Mind, which is, as we should see, directly dependent on our conception of computation.

2 ... and has also been the major theoretical breakthrough behind the computer revolution in the 2nd half of the 20th century.

3 The *Entscheidungsproblem* (the Decision problem) is a problem in mathematics and computer science, originally formulated by David Hilbert in 1928 as one of the major problems in mathematics. The problem asks whether there exists an algorithm that can evaluate a statement in first-order logic as "True" or "False" according to whether the statement is universally valid. In his paper, Turing (3) proves that there is no solution to the *Entscheidungsproblem.*

Nevertheless, this conception of computation is subject to various critique. For example, Smith (2) claims that Turing's account is simultaneously too broad, in applying to more things than computers, and too narrow, in that it fails to apply to some things that are computers. An example of a computational system that cannot be accounted for by Turing are instances when a system requires temporal participation. Smith (1) provides an example of the super-sunflower (p.203). Ordinary sunflowers are effectively coupled with the sun, meaning that they follow the position of the sun whenever they have access to the direction of the sun's light. The super-sunflowers are special because they can track something to which they are not effectively coupled. Smith calls this "noneffective tracking". For example, if the sun sets or goes behind a cloud, the super-sunflower can maintain some coordination with the sun, in such a way that when the sun reappears in some other location, it can still get most of its light and flourish. The super-sunflower defies Turing machine's capacity to achieve temporal participation with another system in a continuous-manner.

<u>Time in computation</u>

Every computation is temporal, yet this fact is neglected by Turing's account of computation. Time is not a factor in the construction of original Turing machines, other than whether a computation can be executed in finite time. Turing Machine do not have the capacity to measure time since there is no regularity as to how one could determine the length of a state change. The general way of determining the time in the traditional computational discourse has been the Big O notation[4]. This mathematical notation does not allow for a particular change in behaviour relative to time, other than the distinction between polynomial and non-polynomial time. Moreover, Turing machines are conceived as a theoretical construct, secluded in a vacuum of their own universe. And since measuring time can be only conceived as a relational property between two systems, temporal participation, as Smith (4) calls it, does not have its place in the original construct of the Turing machine.

In the search for a better account of computation, temporality is an indispensable element. Turing's account is often opposed to the dynamical account of computation in the scholarship. The dynamical account of computing is based on the theory of dynamical systems, as a better way to model natural phenomena as they change over time. Tim Van Gelder (5) proposes the Watt governor metaphor to highlight the salient differences between Turing's and dynamical account. Originally, the Watt governor was designed by James Watt as a way to translate oscillating action of the steam piston into the rotating motion of a flywheel in order to provide a reliable, smooth, and uniform motion for a rotational engine. What makes the Watt governor interesting is that its function could be potentially accomplished both by the traditional computational approach, where the governor would be broken down to a set of algorithms, or by the dynamic version of the governor. Of course, the original Watt governor did not apply anything from modern computation because there were no computers at that time. Instead it relied on an mechanical apparatus that continuously regulated steam coming into the engine. Van Gelder argues that the continuous mechanical version of the governor, describable through the theory of dynamical systems, is more representative of the nature of computation.

Van Gelder (6) discusses are multiple characteristics where the dynamical account of computation differs from the Turing's account. *Firstly*, in the dynamical account, states are the medium of change and have little intrinsic interest, in contrast the computationalist account, where states are among the core constructs. Dynamicists conceive a system as a dynamical landscape, rather than focusing on how the individual pieces are combined to constitute a particular computational structure. *Secondly,* instead of seeing the computational structure as static, the dynamicist approach emphasizes temporality, by focusing on when certain behaviours occur, rather than what the behaviour itself is. *Thirdly,* it is important to study dynamic systems in relation to other systems, rather than in isolation. Thus, dynamicists tend to think of systems as operating in parallel, instead of in serial execution. This also gives importance to coupling and observation of how multiple variables can change each other over time. *Finally,* dynamicists think of a process as ongoing, not starting and not ending anywhere, in contrast to the importance of a particular halting point in the traditional account. They also claim that representation, in comparison to static symbol tokens, can take on more complex forms, such as parameter settings, system states, attractors, or trajectories.

Van Gelder presents the dynamical account in opposition to Turing's account, however, as I argue that they are complimentary. Van Gelder's motivations for the dynamical account of computation is that it might give a better account of natural computation, including cognition. The capacity to account for cognition is also one of the criteria stated by Smith. As Smith (2) points out, these claims are subject to empirical scrutiny and, if computation *"in the wild"* is not as van Gelder characterises it, then his proposal can be invalidated. To support van Gelder's notion, I shall present several reasons why the dynamical account might be better in accounting for cognition.

<u>The role of time in cognition</u>

Time and cognition are inextricably connected in many behaviours which express themselves as temporal sequences. It is difficult to conceive how humans would be able to deal with basic problems, such as goal-directed behaviour, planning, or causation, without some way of accounting for time (7). In comparison to traditional Turing machines, humans are finite beings in finite spaces that depend on finite cognitive means when interacting with their environment. From the perspective of the Darwinian Evolutionary Theory, time is inevitably an important factor in the evolution of our minds. This is particularly interesting in cases

4 The Big O is a standard notation in computer science used to classify algorithms according to how their running time or space requirements grow as the input size increases. It is important to mention it in this paper, as it is a testament to the importance of time in the computational practice.

where humans have evolved the capacity to effectively solve computationally challenging problems. An example of such a problem is the tiling problem, originally formulated by Roger Penrose (8), where humans seem to be able to decide upon a solution in a finite time. In this problem, one is given a set of polygonal shapes, and has to decide whether these shapes will cover the plane; that is, is it possible to cover the entire Euclidean plane using only these particular shapes, without gaps or overlaps? This was shown to be a computationally unsolvable problem by the American mathematician Robert Berger (9). Thus, Turing machines cannot carry out a similar decision in a finite time. I do not claim that by accounting for time, we might stumble on a solution to this problem. However, by accounting for time, we might be able to better describe such problems and consider properties that might allow for a solution. These problems highlight the difficulty of providing a theory of computation that can explain the computational theory of mind. Moreover, it is to a large extent also an empirical issue. These types of problems raise the question of whether the way humans solve these problems is algorithmic or dynamical and how Turing machines would be implemented in the case of cognition.

Furthermore, there are some properties of measuring time that appear to be particularly relevant in a cognitive system. Especially, I am referring to the necessity of accounting for time within a system in relation to another system. According to Smith (4) it is precisely that "computational systems are useful because they participate [...] in the world". Given that the human brain is a physical system with a variety of subsystems that has to constantly interact with systems within which it finds itself embedded, a more accurate model of computation might reflect these properties too.

Rationale

What would a Turing machine with time-continuous properties look like? Or should we reject the Turing model completely? As Smith (2) points out, the metaphors that we use to manifest our conception of computation influenced by our ontological assumptions, methodological commitments, and social and historical biases. Many of these influences have changed since Turing formulated the model of the Turing machine, but some have remained. Amending the Turing model might allow us to formulate a more accurate theory of computation with our contemporary understanding. In this section I argue for two alterations to the Turing machine.

Firstly, the newly conceived Turing machine must have a *continuous temporal* dimension. This amendment will allow the Turing machine not only to be more true to cognition but also to allow for an explicit participation in other systems, hence, allowing for investigation of embedding of the Turing machine in other systems. As time is a *continuous* property, the tape of the Turing machine should be continuous instead of discrete. Such an alteration allows for a more dynamic conceptualisation of the Turing machine, particularly because, given a constant velocity, the spatial distance travelled in trajectories with continuously varying temporal lengths will itself vary continuously.

Second, the Turing machine should have a *circular tape*, rather than an infinite tape in both directions. Using a circular tape reflects common metaphors for time, and as such continuous movement around the circle can allow for an intuitive participation, rather than simply rendering time a structural component[5]. It might also serve as a more explicit reference to the governor metaphor. After all, the success of the Turing machine can be attributed to its function as a model of computation, which in its raw complexity of computation can defy human comprehension. Similarly, the time-continuous Turing machine serves as a model of computation. However, in contrast to the traditional Turing machines, it includes properties that directly reference our existing metaphors of temporality, which will hopefully make the phenomenon of time-continuous computation more amenable to investigation.

Definitions

In this section I define the time continuous Turing machine. The structure of these machines consists of four elements: time, tape, table, and the state of the machine. The first element, *t*, represents time. The position of the machine on the tape is defined as $\varphi(t)$. The tape itself is signified as *T* and is described by the function $T(\omega)$, where ω is an angle and $\varphi(t) = \omega$. In contrast to the infinite tape of traditional Turing machines, the tape in my time-continuous machine is circular. The possible states of the machine can be expressed as a table of states $\{g'\}$, where each state has a corresponding configuration and behaviour.

As in the case of traditional Turing machines, we have a head that moves alongside the tape. For the sake of simplicity, the basic version of this machine moves in a constant motion, which can be defined as $\frac{dv}{dt}=0$ [6]. However, one can imagine that for more complex dynamics, the velocity can be dynamically varied in relationship to time.

In the given position $\varphi(t)$, which gives us ω, the machine can read a value which we have defined as $T(\omega)\in\langle 0,1.0\rangle$Hence the tape is defined as a function that maps angles to real numbers between 0 and 1. This value together with the current state determines in which one of the states $\{g'\}$ the machine will find itself. The machine also contains a function $w(t)$, which makes the head wait for a certain period of time, and a variable *W*, which corresponds to the amount of time that the machine is going to wait until it proceeds to the next state.

The content of the tape of the machine *T* is a continuous function $T(\omega)$. In the most basic version of the machine, it is composed of a set of modifications that can be expressed as a composite linear function. The printing is executed with the function $P(x)$ where $x\in\langle 0,1.0\rangle$. When the machine prints, such modifications to the tape consist of the *printed value* $P(x)$, *location* ω, *and a modified range* $\langle a,b\rangle$. It can be written down as $m_x=[P(x),\omega\langle a,b\rangle]$ .Therefore, we can define the value of the tape

5 We often use movement around a circle to represent time, be it in case of clocks or revolution of planets around the sun. In that sense, the circular tape allows for an intuitive consistency with these metaphors.

6 This means that there is no change in velocity over time, which also means that the head of the machine moves in constant motion.

as $T = m_1 + m_2 + \ldots + m_n$.

An example of a computing machine

We define the transition tables identically to Turing's format, with the only difference being the use of range probabilities for state definition. This is an example of a machine that prints the sequence 101010. . . with the starting interval of $W = 1/2$, which corresponds to a half of a revolution around the tape. The machine starts at $g^t = b$, on a blank tape $T(\omega) = 0$ [7].

Configuration		*Behaviour*	
g^t	$T(\omega)$	*operations*	*final* g^t
b	0	P(1.0),w(W)	**b**
	$(0\ ,\ 1.0\rangle$	w(W/2)	**c**
c	0		**b**
	$(0\ ,\ 1.0\rangle$	W=W/2, w(W)	**c**

Identically to the case of Turing machines, these tables can be also reduced to abbreviated tables or description numbers where all $DN \in \mathbb{R}$.

The super-sunflower example

Earlier I cited the example of a super-sunflower. The system can be simplified to two circular tapes, where one represents the sun and the other represents the desired time-continuous Turing machine. We call the sun *S* and the super-sunflower is *R*. We also introduce the functions $\alpha(S)$ and $\delta(R)$, which stand for the current speed in which the machines are moving. In the case of *S*, the position of the head $S(\omega)$ represents the position of the sun. The machine *R* has access to $S(\omega)$ if the $S(\omega) \neq \langle \pi, 2\pi \rangle$. In such a case we can say that $\nexists \alpha(S)$ for *R*. In other words, *R* does not have access to the speed of *S*. Both can be initially moving in an arbitrary speed. The machine *R* can then be defined as:

Configuration		*Behaviour*	
g^t	$R(\omega)$	*operations*	*final* g^t
b	$\exists\alpha(S), \alpha(S) > \delta(R)$	δ(R)+0.1, w(W)	b
	$\exists\alpha(S), \alpha(S) < \delta(R)$	δ(R)-0.1, w(W)	b
	$\exists\alpha(S), \alpha(S) = \delta(R)$	δ(R)=δ(R),w(W)	b
	$\nexists\alpha(S)$	δ(R)=δ(R),w(W)	b

Given this definition of the super-sunflower, the machine *R* would approximate the speed of *S* based on the size of the amount added or subtracted if the speed of *S* is smaller or larger than its own. The time it would take also depends on the value of the waiting function. Both the continuously temporal elements of the *R* and participation with *S* would be challenging for a traditional Turing machine.

Discussion

The reason for consideration of Smith's super-sunflower example is that it is a system that requires continuous temporal coordination with another system. The traditional Turing machines do not have this capacity because they cannot keep track of continuous time and because they cannot formally participate in another system in the same way as the super-sunflower requires. Addressing these two inadequacies has allowed me to apply the time-continuous Turing Machine to the super-sunflower example.

Van Gelder suggests replacing Turing's account of computation with the dynamical account, however, the proposed super-sunflower machine shows that a complete turnover might not be necessary. Given this compatibility, we can generalize a theory of computation to include continuous time. It is true that the original Turing machines are not a good way to account for the functioning of the Watt governor. However, the time-continuous Turing machines might be a more appropriate option. The proposed machines are a hybrid case between a dynamical system and an algorithm, which raises the question of what counts as an effective mechanism.

In that sense, it is not the case that van Gelder is wrong. It is still possible to formalize the case of the super-sunflower in terms of dynamical equations. However, in the case of the proposed super-sunflower machine, we can give an account of the super-sunflower where the machine maintains correspondence even when it is disconnected from the sun. Thus, the position of the head represents the position of the sun even if there is a disconnect. Therefore, there is no incompatibility, despite van Gelder's suggestion that a dynamical description cannot be computational. My machine is computational, dynamical, and maintains correspondences in periods of disconnect.

Given all these properties, one could imagine a Turing machine constructed to model a particular natural phenomenon. In which case we might be able to consider a contextual relation and participation of the Turing machine otherwise impossible with the traditional conception, as it models the world while engaging in participation with other systems. In simple terms, such a Turing machine could be considered a super-sunflower that can coordinate with any other system, similar to how the universal

7 The reader is encouraged to follow through by drawing a circle to represent the machine, with the head starting at the top of the circle, and then executing the sequence. The value of the tape at the initial location is 0. Thus, given that the machine starts at the state **b**, it will print one and wait for W= 1/2 of the revolution around the tape before it checks again the value on the tape and gets the value of 0. It continues to print 1 and waits the same period. The head is back at the starting position where the value is 1. It will wait W= (1/2) /2 = 1/4 and proceed to state **c**. Since there is nothing at that location, it will proceed back to state **b**, print a 1, and wait W= 1/2. Since the tape at that location is 0, it will print a 1 and wait W= 1/2 . Since it encounters a value of 1 at that location, it will wait *W*/2 and proceed to state **c**. Given that the tape will be again 1 in that location, it will make W= 1/4 and wait 1/4 of a revolution. In such a way, the machine will continue to subdivide the tape and print 1s *ad infinitum*.

Turing machine can execute the computation of any other Turing machine. This would also fulfill the only essential regularity that Smith (4) proposes for computation, requiring that computation be a physically embodied representational process – an active process whose behaviour represents some part or aspect of the embedding world in which it participates. Hence, the definition of a time-continuous Turing machine might alter the very purpose of a Turing machine, as conceived by Turing. Instead of computing a number from the set of computable numbers, the objective would become participation with a system in the world, giving us a rather a different set of limitations and possibilities for a Turing machine.

Conclusions

I have proposed a version of a time-continuous Turing machine that addresses some of the discussed shortfalls of the traditional Turing model, primarily the lack of a continuous temporal dimension. The dynamical systems theory, as a postulate of second-order logic, is still subject to conclusions of the *Church-Turing* thesis. Nevertheless, I hope to have provided a more accurate treatment of computation which is also more aligned with our contemporary understanding of cognition. Unless we succumb to some form of mind-body dualism, the time-continuous Turing machine is being embedded in your mind and realised on the physical system that is your brain. Thus, the set of functions that constitute dynamic system theory must be realisable on the proposed machine. This proposition is a matter of a further proof. Finally, a more detailed investigation of properties arising from the interaction between systems that contain different temporal relativities is required.

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