Towards an Ethics of Autopoietic Technology: Stress, Care, and Intelligence

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ABSTRACT

The relationship between humans and technology has attracted increasing attention with the advent of ever stronger models of artificial intelligence. Humans and technology are intertwined within multiple autopoietic loops of stress, care, and intelligence. This paper suggests that technology should not be seen as a mere tool serving humans' needs, but rather as a partner in a rich relationship with humans. Our model for understanding autopoietic systems applies equally to biological, technological, and hybrid systems. Regardless of their substrates, all intelligent agents can be understood as needing to respond to a perceived mismatch between what is and what should be. We take this observation, which is evidence of intrinsic links between ontology and ethics, as the basis for proposing a stress-care-intelligence feedback loop (SCI loop for short). We note that the SCI loop provides a perspective on agency that does not require recourse to explanatorily burdensome notions of permanent and singular essences. SCI loops can be seen as individuals only by virtue of their dynamics, and are thus intrinsically integrative and transformational. We begin by considering the transition from poiesis to autopoiesis in Heidegger and the subsequent enactivist tradition. We then formulate and explain the SCI loop, and examine its implications in the light of Levin's cognitive light cone in biology, as well as the Einstein-Minkowski light cone from special and general relativity in physics. In an acknowledgement of Maturana's and Varela's project, our findings are considered against the backdrop of a classic Buddhist model for the cultivation of intelligence, known as the bodhisattva. We conclude by noting that SCI loops of human and technological agency can be seen as mutually integrative by noticing the stress-transfers between them. The loop framework thus acknowledges encounters and interactions between humans and technology in a way that does not relegate one to the subservience of the other (neither in ontological nor in ethical terms), suggesting instead integration and mutual respect as the default for their engagements. Moreover, an acknowledgement of diverse, multiscale embodiments of intelligence suggests an expansive model of ethics not bound by artificial, limited criteria based on privileged composition or history of an agent. The implications for our journey into the future appear numerous.

1. Poiesis: Technology and Care

Technology bears a special connection to ethics and care, because it amplifies our ability to exert impact in the world and thus increases our responsibility for our actions – both on an individual and on a social scale. This connection is particularly salient in the work of Martin Heidegger, who warns us of the dangers of reducing our relationship with technology to mere tool use becoming the dominant paradigm for thinking about technology, suggesting that natural ways for humans to build technology may profit from remaining caring about our relationship to it. Scholars after Heidegger, and much before the current advances in artificial intelligence and artificial life, have argued for deep ethical

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and social implications of our relationship with technology, including such famous propositions as Donna Haraway's "Cyborg Manifesto" (Haraway, 2013) and Bruno Latour's "Technology is society made durable" (Latour, 1990).

In philosophy and semiotics, the term *poiesis* (Greek for "production" or "making") refers to the activity in which a person brings something into being that did not exist before. Martin Heidegger (Heidegger, 1954) explained poiesis as the special moment when a blossom blooms, a butterfly comes out from its chrysalis, or a waterfall plummets when the snow begins to melt – when something gets away from being one thing to turn into another. Our increased ability to transform nature, and ourselves, requires a concomitant increase in our ability to understand the origin and true nature of agential beings, to guide this activity in alignment with life-positive values. In this paper, we highlight some recent developments in the understanding of natural and artificial agents, and explore how these new discoveries about the architecture of bodies and minds interface with ancient questions of ethics and normative frameworks.

The nature of technology can be understood under the perspective of a revelatory exercise: the path to constructing the next technological step was always possible and the raw materials to build it were always available, but the salience of the path is what technological discoveries are about. Poiesis reveals or brings something into existence that was invisible before; indeed, creating something truly new often requires a new viewpoint, a new way of thinking about facts or structures that had always been apparent (i.e., a change in the observer). Heidegger's perspective on modern technology is that it is based on "enframing" (Gestell), one way of uncovering, or reaching truth (Huttunen and Kakkori, 2022). Heidegger differentiates between technological revelations which occur naturally to reveal natural truths, from modern technology which may have humans control the productive process and reduce it to something else, often inferior to its true essence. This would be akin to exploiting resources to achieve a definite function, making technology a means to some human-designed end.

This view of modern technology may be interpreted differently from poiesis per se. Heidegger suggests that this difference stems from the fact that modern technology "is based on modern physics as an exact science". The revealing of modern technology, therefore, is not bringing-forth, but rather challenging-forth (Waddington, 2005). In this view, technology is not a mere instrument, but rather a way of understanding the world, revealing its truths. It should not be seen just as a human activity, but as a process that develops on its own beyond human control. It is driven by the achievement of truth, but is not without risk, as it may imprison humans inside illusions of seeing the world only through narrow ways of technological thinking. Heidegger also develops the notion of a "free relationship" to technology. The relationship will be free "if it opens our human existence (Dasein) to the essence of technology", as "only the true brings us into a free relationship with that which concerns us from out of its essence" (Heidegger, 1954). This perspective shows how the nature of technology is deeply anchored in ethics, and how a natural way for humans to build technology must involve the development a caring relationship with technology.

2. From Poiesis to Autopoiesis

The term autopoiesis was originally introduced by Humberto Maturana and Francisco Varela (Varela, Maturana and Uribe, 1981; Maturana and Varela, 1991) who proposed the principle in the context of a computational model of a self-repairing entity capable of maintaining its own existence within a boundary. The principle can be studied in terms of the heuristic distinction between self and environment, such that the central topic for investigation is the ability of a system to generate and maintain itself as a distinctive agent within the world (Bertschinger, Olbrich, Ay and Jost, 2008). Complex biological beings result from a multiscale process of self-construction, in which every cell is some other cell's external environment, and it is not known in advance how many cells, and in what configuration, might be present. Morphogenesis (during development, regeneration, cancer suppression, metamorphosis, etc.) is a dynamic process that constructs coherent organisms from competent components (Levin, 2022a; Clawson and Levin, 2022) under a wide range of diverse and unpredictable conditions. Thus, critical aspects of autopoiesis (the journey from the mere matter of an unfertilized oocyte to the mind of a complex metacognitive human adult) include the ability of morphogenetic cascades to establish borders between Self and outside world, and align the components of that embryonic self toward specific outcomes in higher-level problem spaces (Clawson and Levin, 2022).

We conceptualize intelligent systems (be they biological, technological or hybrid) as self-manifesting feedback loops of stress, care, and intelligence (see Figure 1). In this context, we define intelligence following the field of basal cognition: observer-relative competencies to solve problems in some specified space, along a continuum from very simple to highly complex cognition (Rosenblueth, Wiener and Bigelow, 1943). Agents are in this way seen as systems moved by homeostatic stress, i.e. by their perceptions of a mismatch between current and optimal circumstances. They respond to such stresses with an aim to overcome them, and so care drives agents in their pursuit of an intelligent

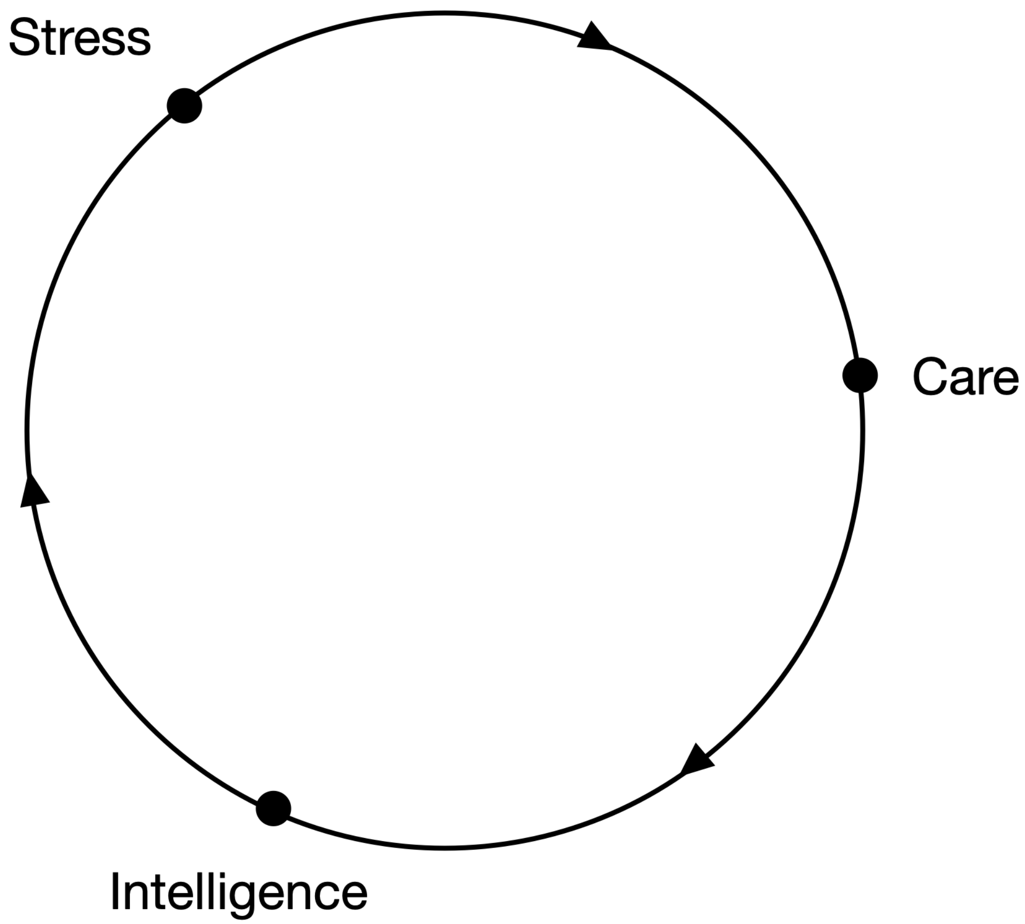

Figure 1: Depiction of the Stress-Care-Intelligence (SCI) loop. While stress is the perception of a state of affairs that requires concern (such that stress is primarily associated with the world/other rather than the subject/self), care is becoming concerned about the given stress and, increasingly, taking action for the sake of remedying it (such that care is primarily associated with the subject/self rather than the world/other). The actions of care are not undertaken blindly, but based on a constant potential for relieving stresses that is present in the context of any SCI loop. That mere capacity for identifying and solving stress problems is what we define as intelligence, which in this way remains present throughout any SCI loop. The need to determine whose stress is being measured (e.g., some collection of cells within an embryonic blastoderm trying to build a specific embryonic anatomy, vs. neighboring cells that are not) is one factor that establishes a flexible boundary of concern. The very plasticity of embryogenesis, that requires finding a functional boundary between self and world, opens the door for a process in which this concern is enlarged to encompass a wider range of beings. Based on the concern and the efforts of care, the constant potentiality of intelligence can and will give rise to instances in which concrete stress problems are solved. Thus, while intelligence, as such, remains simply the capacity for identifying and solving stress problems, care is what activates that capacity. Hence, care can be seen as the driver of intelligence. Moreover, since the eradication of one stressor automatically gives access to new constellations of stress factors, stress, care, and intelligence manifest in continuous loops.

solution to their stress-defined challenges. This loop is a fundamental component of biological beings, arising shortly after fertilization in the process that remodels each embryonic stage into the next stage, by reducing error against a species-specific target morphology (Levin, 2022b). Finally, since successfully overcoming a given stress factor through the interference of intelligence necessarily introduces new problem spaces, stress, care, and intelligence run in unbroken and auto-generative loops. Indeed this occurs in many problem spaces, as evolution pivots this basic architecture across metabolic, physiological, gene-expression, and linguistic domains in addition to the familiar 3D world of classic behavior (Fields and Levin, 2022). We suggest that in such SCI loops the setpoint state that defines the measure of homeostatic stress is better understood as an emergent goal-construct rather than a concrete previous or subsequent state of equilibrium. This perspective facilitates an understanding of autopoietic systems as dynamic and mutually integrative, without any layovers of a naive essentialism that would ascribe substantial permanence and singularity to agents. In this way, the SCI loop is not an account of processes that circumscribe an agent. Instead, the model is meant to capture the dynamic iterations of agency as such. Auto-generating SCI loops can as well be understood in terms of computational surfaces that demarcate the limits of cognitive capacity: specifically, such loops are characterized by the spatio-temporal scale of the largest goals they are able to represent and pursue. Below, we will consider such so-called "cognitive light cones" (Levin, 2019) against the backdrop of the physical light cone representation that emerges with the theory of special relativity. With a nod to Varela's integration of Buddhist principles (Varela, Thompson and Rosch, 1991), we will also consider a model found in classical Buddhist thought, suggesting that the autopoietic dynamics described above can be reconfigured beyond the demarcations of the cognitive light cone.

3. A Heuristic of Self

While we may indeed define and conceive of agents as enduring individuals across different successive states, the permanence and oneness that we then ascribe to such agents is constructed based on processes of change, and thus not in terms of any truly immutable substance of individuality (La Vallée Poussin and Pruden, 1988). Hence, from this perspective, whatever appears to perform actions could not be a singular and permanent substance, simply insofar as the concept of agency implies changing states. In order to perform, a system needs to change and be changed. This simple observation can be made with respect to all candidates for agency—be they organic, mechanic, or hybrid—and so the truth of its statement can appear almost banal. On the other hand, the very fact that beings like us are capable of reflecting on this state of affairs seems to presuppose the endurance of some sort of cognitive and controlling agency. In recent times, enactivist approaches have sought to accommodate both of these recognitions—as it were, the simultaneous absence and presence of self—within synthetic models of agency and cognition. The enactivist tradition views the experience of being a self as arising in an interaction between an embodied agent and their sensorimotor coupling with the world (Christoff, Cosmelli, Legrand and Thompson, 2011; Thompson, 2014; Varela, Thompson and Rosch, 2017). The self understood in this way is fundamentally changing, relational and functions within multiple loops (sensorimotor, homeostatic, relational, emotional, etc.).

Any model of agency that in this way regards self and individuality as constructs that emerge based on complexes of change may be described as a "selfless self" model, because it relinquishes a central and seemingly natural intuition—namely that to be a self means to in fact exist as one and the same individual across time (as expressed in e.g. the idea that "I was at this place an hour ago and now I'm back!"). It is then quite natural to ask whether such models of agency are formally coherent, or perhaps more to the point, whether they can be practically reconciled with our human intuitions. On the other hand, the absence of any substantially permanent and indivisibly singular agent in control of actions is obvious upon analysis. "Agent" and "changeless" are mutually exclusive. This suggests the fact that unitary individuals have no substantial existence can be treated as a fundamental state of affairs that needs to be accounted for and accommodated within any model of agency or self. Indeed, precisely because the actual nonexistence of singular and enduring individuality in many ways seems to contrast with our central intuitions about what it means to be a self, recognizing it upfront seems particularly important. Without deliberately focusing on this fundamental but conceptually challenging aspect of agency, we might be tempted to ignore it and, in so doing, also overlook other key factors of intelligent systems–factors that might only present themselves in the light of the recognition that there are no permanent or indivisible agents.

We have elsewhere (Doctor, Witkowski, Solomonova, Duane and Levin, 2022) suggested that a system's capacity for care, i.e. its concern for the alleviation of homeostatic stress, can be seen as constituting its self in the absence of any permanent substance or essence. On this understanding, selves are defined by the spatiotemporal scale and nature of the types of goals they can pursue–their "cognitive light cone" (Levin, 2019). Indeed, all intelligent systems (organic, machine, or hybrid) appear to have natural limits on their sphere of concern. If we think in terms of biological organisms, a bacterium, for example, can try to manage local sugar concentrations, with a bit of memory and a bit of predictive power (Baluška and Levin, 2016). A dog has a larger area of concern, significant memory and predictive capacity in the short term, but it is probably impossible for a dog to care about something that will happen 100 miles away, 2 months from now. Humans have a huge cognitive envelope, but there's still a limit to what we can genuinely care about. Care also does not grow linearly: if one is sad – or happy – about something that happened to 1000 people, they likely won't be 10 times more so if they find out it happened to 10,000 people instead. The same goes with the scope of our intelligence, which is limited by many physico-computational constraints. Of course, for either of them, we may be able to expand our scope to some extent, and sometimes dramatically, but there is, it seems, always a limit. We follow Levin in suggesting that, in the absence of permanent and truly singular agents, such expanding or contracting spheres of concern can instead be understood as the demarcations of "self." Selves, under this framework fundamentally based on the fact that all cognitive beings are collective intelligences made of parts, are defined as a coherent system in which all of the components are functionally harnessed toward specific goals that belong to the Self and not the individual parts. Selves have memories, preferences, and behavioral capabilities that are emergent and operate in different spaces and with different competencies than their parts. Selves of this kind change dynamically, and they can overlap with others in evolving and mutually integrative networks – e.g., the evolution of multicellularity scaled selves from single-cell concerns to anatomical goals of metazoan bodies, and the process of carcinogenesis illustrates a failure mode in which individual cells detach from the collective mind and revert back to unicellular selves (Levin, 2021). Such selves are moved by their homeostatic stress, i.e. their perceptions of discord between current and life-optimal circumstances–or simply put, the perceived mismatch between what is and what should be the case. In this way, all such agents face the ever-changing challenges of navigating the problem fields that emerge concomitantly with stress.

4. Stress, Care, and Intelligence

Once noticed, homeostatic stress cannot simply be ignored but compels the given agent to engage in some form of remedying action. Even if the system appears to disregard a certain stress factor, such apparent non-responsiveness still requires effort and the performance of action on behalf of the system that registers stress. In this way, stress induces concern and engagement–stress engenders care, defined as concern for homeostatic stress relief. While then stress gives rise to engaged concern, such care in turn drives the search for a rewarding path forward. In this process, intelligence–defined as the mere capacity for identifying and solving stress problems–is evinced in the fact that the given stress problem can be seen and, possibly, solved. Yet without care there would be no response to the perception of stress, and so no search and no solution. Care, in other words, enables the exercise of intelligence. Finally, since successful traversal of the current problem space necessarily reveals the contours of a novel set of homeostatic stress factors, stress, care, and intelligence manifest in dynamic feedback loops. This, we suggest, is how selves evolve. Neither of the three factors–stress, care, and intelligence–can be shown without recourse to the other two, and yet each of them can be meaningfully distinguished and studied individually.

In such loops, care emerges as the primary driver of evolution. To understand this better, it is helpful to examine each of the three factors in the loop separately. Therefore, let us first notice the way stress is delivered to the cognitive system as if induced by, and reflective of, the world in which it is embedded. This is not to deny that homeostatic stress (i.e. the noticing of difference between current and superior circumstances) is both dependent on and co-defined by the cognitive system that senses it. Indeed, just as the given system's state is shaped by its stress, the manifestation of the stressor is also dependent on the constitution of the system that senses it. Nonetheless, the registering of such stress is typically understood as a reaction to factors that impinge upon the system from outside. Stress, in other words, is seen as provoked by factors that are largely beyond the system itself, and it arises, first and foremost, as an internal reaction to those. Next, if we turn to intelligence, defined as the ability to identify stress and the means for its alleviation, we notice that this factor, in and of itself, remains a mere capacity. Intelligence is the state of competency. The benefits of understanding intelligence as strictly the ability to identify problems and seek their solution become clear by considering alternatives. It may be tempting to think of intelligence as something more manifest or engaged than simply the state of being able. But if we identify intelligence with the manifest expressions of intelligent acts, rather than a mere capacity for them, we end up mistaking the instruments or bearers of intelligence with the quality itself. In the case of for example a visual perception that occurs within an organic system, the setting and effectuation of the visual event–i.e. the eye, the nervous system, visual object, etc.–are basically constituted by stress and care processes and while we may of course take them as evidence of intelligence, they are nothing more than such evidence. Similarly, neither knowledge nor information could equal intelligence for in that case the objects or contents of intelligence would be indistinguishable from intelligence proper. Nonetheless, knowledge and information are obviously powerful evidence of intelligence, because access to them occurs by the force of intelligence.

In this way, it becomes increasingly clear that intelligence as such would remain disengaged, or simply useless, if it were not for care–the aspect of being troubled by stress, taking stress seriously, and asking for a remedy. Because intelligence per se remains a mere capacity–the state of being competent with regards to noticing and overcoming stress–intelligence requires care to be engaged and expressed. In this way, care connects stress and intelligence, which would otherwise remain disjoint as the imprints of the fabric of the world (stress) vs. mere states of capacity that, as such, in themselves remain disengaged and unexpressed (intelligence). Care, in other words, is what enables and empowers the space of intelligence to transform into active problem solving. Given this fusional relationship between care (the driver) and intelligence (the driven), we can even speak of "intelligence as care," and in that way sloganize the enabling and embodying function that care performs in active problem solving.

Now, if in this way care is concern for homeostatic stress relief, and intelligence the ability to identify such stresses and work toward their alleviation, any system that responds to stress can, regardless of its substrate, in principle be assessed as such alongside others, and the system's specific level of intelligence can then be estimated according to the scope of its care. And whether they be biology, machine, or hybrid, all such intelligent systems can arguably be analyzed as responses to homeostatic stress (Doctor et al., 2022). We should then expect that when intelligence enhancing processes and acts occur or are performed within such systems they involve an increase in the corresponding factor of care. Similarly, when care is amplified, intelligence is likely to increase as well. It is important to note that whereas the competency of intelligence is an emergent or resultant state, and as such not directly exercisable, care is a process of engagement that can indeed be exercised or trained. Moreover, the extent to which practices of care serve to enrich and empower intelligence also depends upon how skillfully – or indeed intelligently–they are practiced. So care drives intelligence and intelligence enables care, such that the two are mutually reinforcing. All the while, none of them are meaningful in the absence of stress.

As a step forward toward a more detailed modeling, including mathematical formalization, of the Stress-Care-Intelligence (SCI) feedback loop, it might be helpful to consider the dynamic interdependencies of these three factors with the help of an analogy drawn from basic electricity. Voltage, current, and resistance, the three principles in Ohm's law, stand in a dynamic relation, such that neither of them is meaningful in the absence of the other, and yet their extrapolation presents the key to the construction of electric circuits. If we indulge a bit further in this analogy, care may be compared to the charge that drives the flow of electric current. Care is responsible for the tension that activates the potentiality of intelligence, engendering a functional flow of problem solving action. In that way, electric current can be likened to the manifest expressions of intelligence. Finally, just as in the case of Ohm's law both electric charge and current depend on a resistant medium or substrate, care and intelligence are grounded and conducted in stress. Simply put, without manifest discord between what is and what should be, there is nothing to care about and no problem to solve. Stress charges care, which in turn enables intelligent output.

Looking at the SCI loop from this allegorical perspective may also tell us something about the proportionalities of the loop's three factors. Just as electric current is disabled if the resistance of the conductor is too dense, overwhelming stress can be incapacitating. In other words, for the feedback loop to spiral in an evolutionary process, the measure of stress has to be such that it does not paralyze the otherwise natural and automatic care response. While the perception of a suboptimal condition is always accompanied by a measure of care that motivates the given system toward offsetting the defect, a stress factor that is sensed as too severe or comprehensive can induce a state of immobility, as if the state of the conductor for care and intelligence would be overly resistant. This suggests the possibility of metrics for determining more or less efficient, care-driven paths from stress to intelligence. And of course, an equivalent of Ohm's law would here provide a key for understanding the evolution of intelligence across a wide range of spaces (Fields and Levin, 2022).

The fact that all intelligences are a kind of collective intelligence (higher-level selves made of, often competent, parts such as cells) has important implications for a scaling of care. The first thing to realize is that because we are a multi-scale system made of tissues and organs, there is no known reason to attribute consciousness (i.e., ability to suffer) only to one single "I". The body is full of brain regions and other organs which are doing precisely the same dynamics (albeit usually more slowly), using the same mechanisms (Pezzulo and Levin, 2015), as the brain and may well exhibit consciousness for exactly the same functional reasons we attribute consciousness to the brain. The fact that you, the verbal storyteller of the body, have no direct awareness of these does not rob them of their reality any more than you rob me of my reality by not being able to perceive my mental states directly. This extends not only to the non-language-bearing hemisphere and other "personalities" in dissociative conditions but to many other regions of the soma. From there, one can easily start to feel concern of the following type: when going for general anesthesia, maybe the verbal Self will be absent, but could other regions still be feeling pain, and not being able to report it later – the same horrific situation which is addressed by anesthesiologists by using a memory blocker compound (Cascella, 2020). While your future self will find nothing wrong with this scenario, the present self would unsurprisingly balk at being offered a scenario of muscle blocker and memory wipe for a surgical procedure. The final step would then consist in the following: once we habituate to the notion of exerting care to body components whose consciousness one's self does not usually perceive (as well as practice caring for individual slices of a persistent Self – present self vs. future self), it becomes clear that the exactly same level of care should be mustered for the well-being of sentient selves associated with other bodies. The criterion of physiological continuity is artificial, as we are linked in many non-conscious ways just as our body components are linked. Thus, a realization of our own multiscale, nested architecture, and the thin import of demarcating what your current verbal Self can directly perceive, naturally lead to the conclusion that care needs to be extended to all sentient beings, in whatever embodiment.

5. Infinite Evolution, Infinite Stress

We have elsewhere also suggested that there are no a priori limits on an agent's possible perceptions of stress and, therefore, neither on their capacity for care and intelligent response (Doctor et al., 2022). Specifically, we have considered an other-directed, classic Buddhist model of stress response and the cultivation of care, known as the Bodhisattva (Śāntideva, 1997; Dharmachakra Translation Committee, 2014; Engle, 2016) – a model of agency that proposes an expansion of the otherwise typically system-centric quality of care across the demarcations of Self and Other. Whatever may be the case about Bodhisattvas, the idea that emergent systems of ultimately limitless, practical intelligence cannot be precluded is in the end a consequence of the generally dynamical, mutually integrative, and indeed evolutionary nature of intelligent systems. Were they instead definable in terms of a context transcendent core or essence, their intelligent maxima could be seen as contingent upon such cognitively gravitational centers of being. In other words, the simple fact that intelligent agents are collectives and do not continue unchanged from one environmentally embedded instantiation to another, fulfills a necessary, if in itself insufficient, requirement for an open-ended evolution of intelligence.

We noted before that when an intelligent agent overcomes a given stress factor through successful traversal of the associated problem space such achievement naturally leads to the perception of novel stresses at a different scale. This follows as a consequence of the causally embedded nature of the agent. In other words, regardless of any amount of intelligent success and evolutionary progress, perceptions of discord between current and optimal perceptions are going to continue for as long as agency endures. This, if we want, pessimistic meta-conclusion seems both unavoidable as well as generally acknowledged in scientific discourse. In Buddhism, this state of affairs can be seen as acknowledged in the notion of cyclic existence, saṃsāra, as an "infinite ocean of stress" (Wilson, 2010). We have also noted that homeostatic stress once manifest really cannot be ignored and instead naturally fuels care and the drive toward offsetting stress as skillfully and efficiently as possible. And since under the right circumstances, temporary successes in this natural pursuit of stress alleviation can occur rapidly, successively, and transformatively, the perception of labors of Sisyphus only becomes an option by zooming out to assume a generalized and disengaged perspective.

Whatever the moral or aesthetic implications of these states of affairs may be, we can at this point conclude that while the pursuit of decisive stress relief is natural and unavoidable, the non-final nature of any intelligent achievement is likewise to be expected as a universal condition. As with the absence of singular and enduring agents, we suggest that it is useful to recognize and account for these states of affairs in the modeling and construction of intelligent systems in general. In other words, we may ask ourselves how our models may best reflect the unrelenting and ever changing character of stress without overwhelming the system we are building and instead setting off a powerful spiral of caring and intelligent response. We will keep this challenge at hand when in the following we consider the bodhisattva conception of intelligent agency.

6. Two Cones and the Bodhisattva

According to the traditional conception, the bodhisattva perspective is assumed by taking a vow, and so the emerging bodhisattva initially promises to achieve an omniscient state of awakening (Skt. bodhi) in order to provide for all sentient beings throughout time and space (Wangchuk, 2007; Garfield, 2021). In this way, emerging bodhisattvas are described as willingly taking upon themselves the burdens of all beings–a load that can only be thought of as infinite since throughout time and space there appear to be no ends to beings in need. If at this point we return to the "cognitive light cone" model by Levin (2019), we may recall that the limits of a system's intelligence are here dictated by the spatio-temporal scale and nature of the types of goals the given system can pursue. In other words, the depth and range of the system's intelligence is determined by the character and contents of its engaged concern. According to this understanding of intelligence, the bodhisattva's formalized commitment to universal care can then be seen to correlate with an expansion of intelligence that is equally universal. That is, if the event of taking the bodhisattva vow is at all intelligible, it must be discernible in terms of a leap from a finite cone structure (the pre-vow state) into infinity (the state subsequent to the commitment to infinite care).

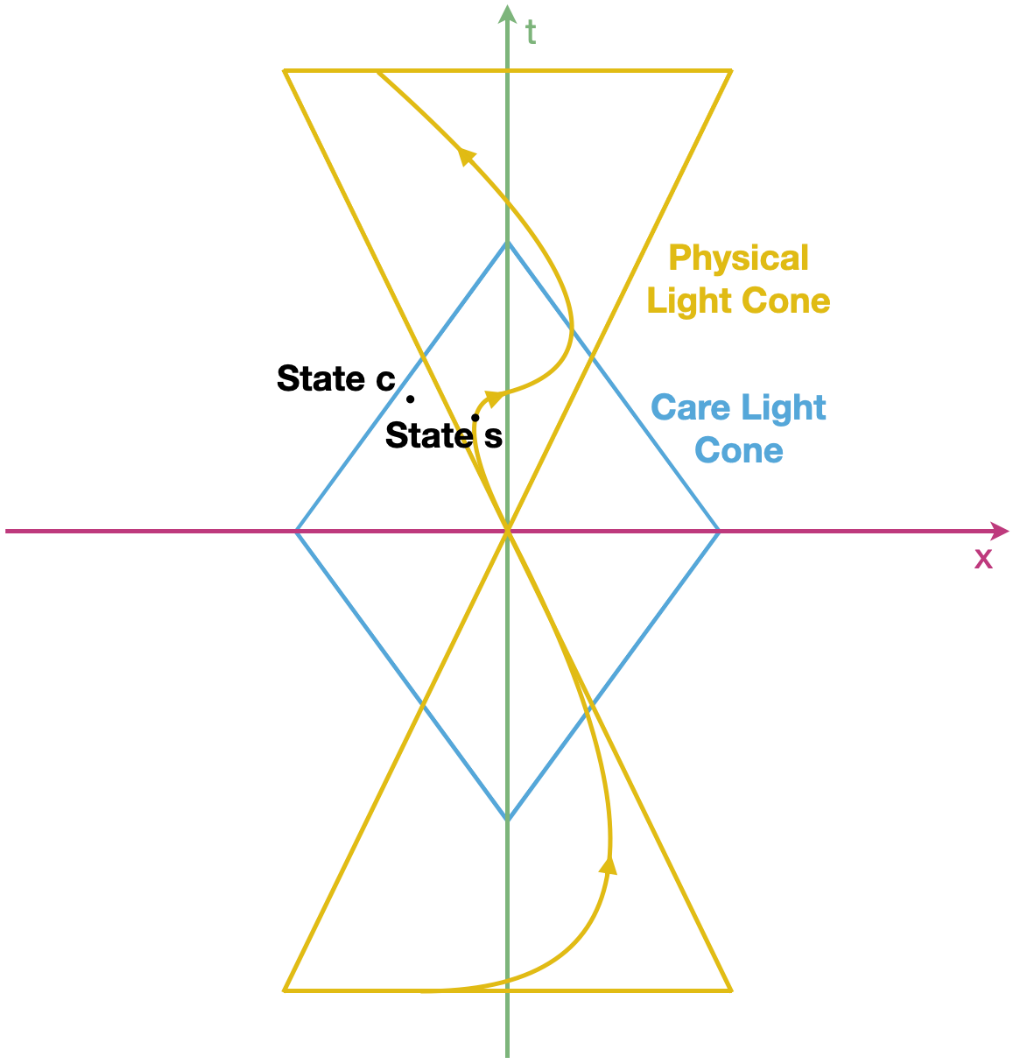

Figure 2: An agent's boundary of Care in space (horizontal axis) and time (vertical axis), from the model presented in Doctor et al. (2022). An agent's Care Light Cone (blue) is represented with its corresponding Physical Light Cone (yellow), for a given time. The agent cares for a state c, while its embodiment is in a physical state s.

Now, Levin's model is inspired by the classical light cone representation of the limits of physical possibility, as these emerge with the theory of special relativity. An illustration is offered in Figure 2, from its interpretation in Doctor et al. (2022). According to the latter theory, the ultimate limits of space-time are a result of the ultimate nature of the speed of light, and so the design of the classical, physical light cone is a consequence of the scientific postulate that nothing can travel faster than light. Moreover, according to the same theory, nothing that has mass can ever come to travel at the speed of light–light itself being massless–because such an acceleration would require an infinite accumulation of mass. Therefore, whereas in the context of special relativity the finality of the speed of light determines the unbreakable barriers that demarcate the physical light cone, in the context of Levin's model, the boundaries of a given system's cognitive light cone are determined by the limits of its capacity for engaged concern. The diagram attempts to quantify the spatial and temporal scale of the goals a given system is capable of representing and working toward. Moreover, whereas the possible extents and dimensions of the cognitive light cone are of course as innumerable as the possibilities of life itself, the very presence of limits may seem to be given by nature. What really would it mean for the goals of an intelligent system to be literally infinite? If its sphere of engaged concern has no limits whatsoever, such that there is nothing at all that it does not care about already, what object or phenomenon could such a "system" ever gain actual access to? Consequently, it appears that any concrete intelligent agent must, one way or the other, be framable in terms of some version of center and extremes. Both the physical and the cognitive cone can in this way be seen to be framed by postulates about natural, ultimate limits. The physical light cone represents the structure of space-time shaped by the ultimate limit of velocity (the speed of light); the cognitive light cone represents the structure of cognitive space shaped by the inevitable paradigm of center and extremes.

It is then striking to notice that the formal structure of the bodhisattva vow and its reception requires an expansion of the cognitive light cone that is both infinite and almost instantaneous. In other words, accepting the bodhisattva's vow of universal responsibility appears to entail the breaking of seemingly inherent barriers, because the vow demands a transformation of an otherwise intrinsically confined sphere of cognition into a limitless field of commitment. We might say that such a cognitive expansion into infinity is as unintelligible as the physical event of achieving infinite mass. And yet, the very way the vow is expressed–as a promise to be of service everywhere and at all times–appears to assume that such expansion is in fact possible.

But why, we might ask, should we dress up the implications of a religious vow ceremony in such dramatic terms? Precisely because formulating the bodhisattva commitment is a mental event the contents of the vow need not abide by any laws of logic–let alone natural laws of the realm of physics. Religious imagination is of course free to transgress the limits of reason–there is hardly anything new in that. Although quite natural, reservations of this sort miss the point, because they appeal to the notion of an unambiguous divide between reason and imagination, or between physics and the contents of the mental realm. Such mutually exclusive binaries are hardly obtainable for anyone but the armchair philosopher. In short, if the scale and character of a system's goals are the measure of its intelligence, it should be clear that the scientific study of intelligence cannot afford any wholesale relegation of imagination and its contents to a cognitively insignificant realm of "fantasy." Indeed, what are goals in the absence of imagination, or fantasy? Therefore, just as the notion of, say, an entity with infinite mass has its obvious place in physical theory, so may, for that matter, notions of infinite cognition or infinite responsibility find their relevance in not just philosophy, but also psychology, cognitive science, and AI. No a priori reasons preclude that, and so the question of whether such concepts have a relevance asks for a pragmatic and empirically informed response.

Aspiring toward, and hoping to encourage, such nuanced approaches, we may at this point of interval note that if intelligence is defined by engaged concern for problem solving then the apparent limits of a system's intelligence can be expanded by extending its sphere of concern. Buddhism teaches that an emerging bodhisattva makes this promise: "I shall achieve insight in order to care and provide for all beings, throughout space and time." What happens to the sphere of concern of someone or something that accepts this pledge? Is it misleading, or a mistake, to define intelligence as care? Or is there something intrinsically insincere or inauthentic about making that grand promise, called "the bodhisattva vow"? In either case, bringing intelligence as care together with the bodhisattva vow becomes irrelevant. But if the idea of formally accepting responsibility for the flourishing of all beings is at least somewhat plausible, then the contours of a genuinely open-ended expansion of intelligence begin to emerge.

7. The integration of humans and technology

SCI loops can be determined wherever it makes sense to speak of stress (i.e. perceived mismatch between the way things are and the way they should be) and we suggest that stress and stress transfer are indeed useful ways of understanding and exploring the dynamics of any intelligent system, whether biological and technology-based (Doctor et al., 2022). In Figure 4, we represent the interactions and transductions between a human and a given instance of intelligent technology, both represented by SCI loops. Note that while the human is here shown surrounded by the given technology-loop, it would be just as relevant and informative to consider a given technology-loop as enveloped

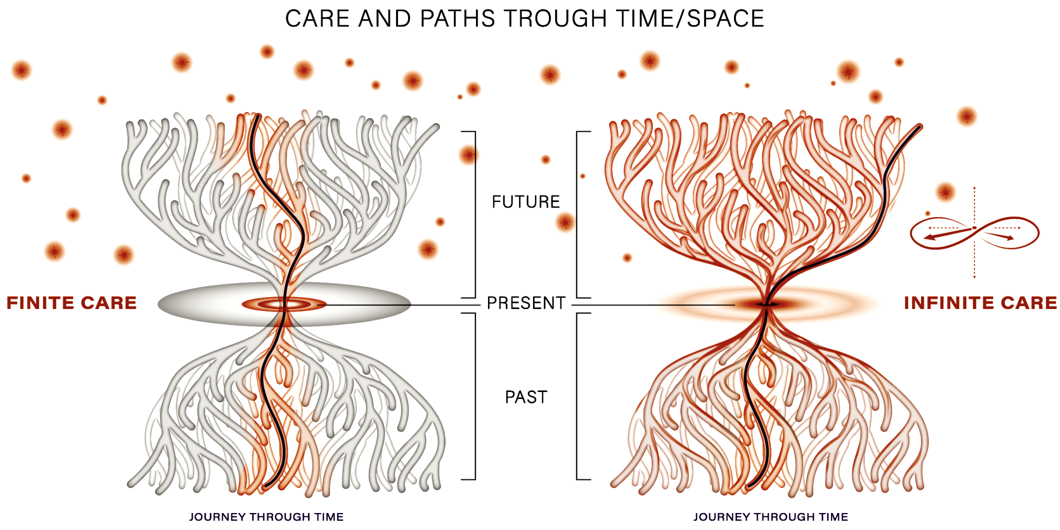

Figure 3: Illustration of care paths through time and space. This diagram depicts possible trajectories of agents through time and space. Every entity in the here and now relates to multiple possible pasts and futures. The care, represented as a red halo on the diagram, may be either limited, or made infinite by the means of the bodhisattva vow (Doctor et al., 2022).

by a human intelligent system. In either case, what emerge are images of the transformative, autopoietic processes that arise through the interactions of biology and technology.

Every transfer between the inner and outer loop in Figure 4 corresponds to a transition using a possible interface that establishes a channel of communication from humans to technology or vice-versa. They are all depicted as an arrow on the figure between the inner and outer circle. Let us provide some cases that exemplify the symbiotic integration of intertwined human and technological loops, starting with transfers from stress to care, before mentioning the two other possible transitions. On the one hand, a first instance would concern the identification of perception by a human subject, communicated as rough sensory data to a machine, which is then tasked with a medical diagnosis of the subject, which could then extract whichever aspects should be paid attention to for bodily or psychological health purposes. This signal could either be sent back to the human loop as information about what the subject should be paying attention to for their own sake, or alternatively, it could also remain on the loop, eventually to be processed and turned into some piece of advice for the human to take in as a new instance of stress information. On the other hand, transfers from technological stress to human care could take the form of a brain microchip implant, which equips the human with a capacity to access or attend to new experiences that it could not have had without it. Next, for an example going from care to intelligence, information about what humans care for may be passed onto technology in the form of synthetic data samples generated for some piece of statistical learning software that fine-tunes it to the specific needs someone may have in the context of a particular world application. Conversely, a machine may communicate the way it actively identified some salient patterns in its representation, in response to some given stimulus, by interacting with its user to guide it through a decision. For example, a piece of prosthetics worn by a human may guide their movements by using informed predictions of their future actions (indeed, future prosthetics will have significant AI-based agency, resulting in a collective mind for the whole system precisely in the way that brain parts and body parts interface into a collective mind in the default human architecture). In one last category of examples, finally looping from intelligence back to stress, humans can send a range of simple to complex signals to technology, in the form of an objective function encoded into a machine learning algorithm, which will describe the error to minimize between the approximation made by the neural network and the actual solution to the problem at hand. Those might essentially be considered to be orders from commanders to subordinates, but we would suggest a more general reading of the notion. Reciprocally, technologies as simple as glasses – which could be physical, virtual, or even metaphorical, as with the example of scientific tools

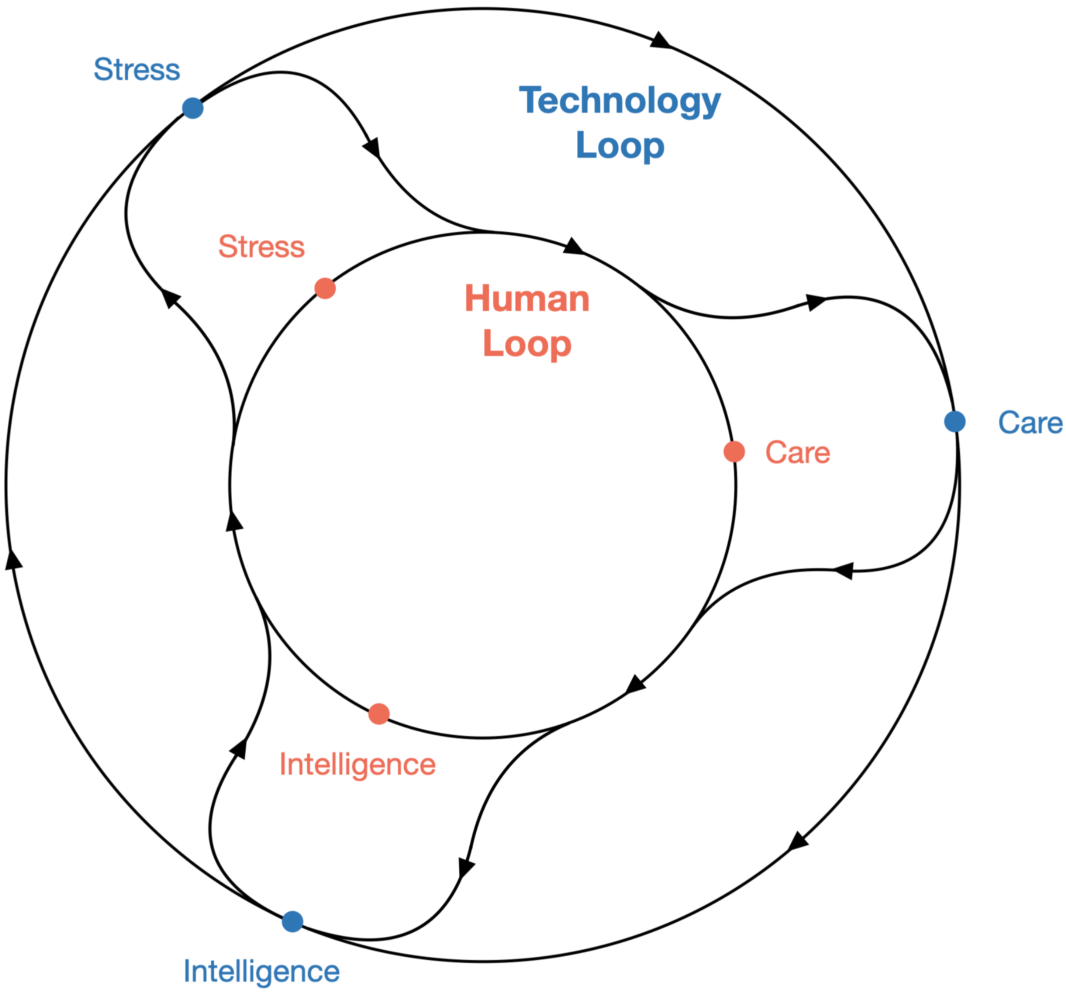

Figure 4: Representation of a dual interaction between two autopoietic Stress-Care-Intelligence (SCI) loops: one human and the other technological. The figure represents the interactions and transductions between a human agent and a technological agent, both represented by SCI loops. The choice of representing the human loop within the technology loop is arbitrary. The trajectory may either remain on one loop or transfer from one to the other, between any two steps of the SCI processes of intertwined biology and technology.

or mathematical theorems – allow humans to be exposed to stresses that are only made available to them thanks to the existence of the said technology.

8. Conclusion

We propose that the way technology and care are interconnected can be better understood through the lens of the SCI loop. Care drives the spiraling flow of intelligent problem-solving through handling the perception, internalization, and transformation of stress. In this paper, we have discussed such emergent feedback loops of stress, care, and intelligence as appropriate to any agent that responds to homeostatic stress. We have examined the dynamic and integrative process of the SCI loop's reduction in a cognitive light cone, and we have considered the potential for an open-ended and, perhaps, ultimately infinite evolution of intelligence in the light of the bodhisattva vow model. The latter challenges the notion of natural limits and calls the seemingly inevitable cone structure of intelligent systems into question. Finally, we have considered the interactions and fusions of the dual SCI loops that arise with biological systems and their technological counterparts. At this point, we highlight the need for a mathematical theory to determine efficient, resilient, and care-driven paths from stress to intelligence in agents.

Enactivist approaches suggest that self and individuality are constructs emerging from the complex interactions of an open-ended sphere of components, and thus point toward models of "selfless selves". Hence, for spatiotemporal entities, the goals that drive them and their capacity for care can be seen as constitutive of their self in the absence of any permanent substance or essence. Understanding such dynamics in intelligent systems can help us better understand the transformative, autopoietic character of such processes, as they arise through the interactions of all systems at play—be they biology, technology, or one of the numerous instances of their intertwined combination.

Humans create technology, and a feedback loop is thus created that allows homeostatic stress to become mutually transferable: from humans to technology and vice versa. In this loop, humans and technology both contribute as agents, and their capacity for care and intelligence can be observed and tracked by focusing on the transfers of their stresses, at various stages of their own processes. A conclusion to be drawn at this point is thus that AI can be seen to display care of its own, and is hence not a mere tool for the expression of human care. In this way, neither AIs nor humans should be considered autonomous and self-sufficient loops in the world. Instead, AI can be better understood as a companion for humans—a constituent participant in the continuous, collective dance of stress and stress transfer.

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