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Keywords: subjective time; information accumulation; gravitational analogies

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A Geometric Model of Human Life Trajectories

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Abstract

Human subjective time exhibits a universal acceleration with age which is described using a formal analogy between the dynamics of subjective time and gravitational time dilation in general relativity. For that it is constructed a two-dimensional informational state space defined by accumulated structured experience I(t) and future directed value λ(t). An informational potential Ψ(I,λ) induces a metric of subjective time analogous to the Schwarzschild metric. This framework naturally yields horizons, points of no return, and black hole like collapse corresponding to terminal cognitive decline. The model provides a unified geometric interpretation of aging, burnout, life cycles, and the phenomenology of time.

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1. Introduction

The rapid growth of the elderly population is a major global demographic and social issue [1–4]. Human subjective time exhibits a universal acceleration with age, a phenomenon widely documented in psychology [5,6]. The subjective experience of time has long been recognized as one of the most variable and elusive aspects of human consciousness. Philosophers, psychologists, and neuroscientists have all attempted to explain why time appears to accelerate with age, why novelty expands subjective duration, and why the final phase of life is often characterized by a collapse of temporal structure. Despite the richness of these traditions, no unified mathematical framework has emerged that captures the geometry of subjective time or the structure of human life trajectories. Early philosophical accounts emphasized the qualitative nature of temporal experience. Henri Bergson described time as durée, a continuous flow shaped by memory and consciousness rather than by physical clocks [7]. William James noted that subjective time depends on the density and vividness of experience, anticipating later empirical findings on memory and temporal perception [8]. Martin Heidegger framed human existence as fundamentally temporal, structured by anticipation, projection, and "being toward death," highlighting the existential dimension of temporal experience [9]. These perspectives anticipated many phenomenological features of subjective time but lacked formal structure, metrics, or predictive power.

In psychology and cognitive science, researchers have identified several mechanisms underlying temporal perception. Robert Ornstein proposed that subjective time depends on the amount of information processed, with memory compression accelerating perceived time [10]. David Eagleman demonstrated that novelty, surprise, and emotional salience expand subjective duration, while routine compresses it [11]. Marc Wittmann and colleagues documented the universal acceleration of subjective time with age, linking it to changes in memory density, attention, and cognitive processing [6,12]. These empirical findings provide essential ingredients for a theory of subjective time but do not offer a geometric or dynamical model.

Parallel developments in physics have revealed deep connections between time, entropy, and information. The work of Bekenstein and Hawking established that black holes possess entropy proportional to the area of their horizons, suggesting that information is fundamentally geometric [13,14]. Jacobson showed that Einstein's field equations can be derived from thermodynamic

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principles, implying that spacetime curvature emerges from entropy gradients [15]. Verlinde proposed that gravity itself may be an entropic force arising from information theoretic considerations [16]. The holographic principle, articulated by 't Hooft and Susskind, proposes that the full dynamics of a physical system can be encoded on a lower dimensional boundary [17–19]. These ideas provide powerful mathematical tools for understanding how information shapes temporal structure, but they have not been applied to human cognition or life trajectories.

Attempts to model human life mathematically have remained largely statistical or phenomenological. Life course sociology analyses trajectories of education, work, and health but does not address subjective time. Dynamical system approaches in psychology model attractors and stability but lack a metric structure. Information theoretic models of aging focus on biological entropy rather than subjective temporal experience. None of these frameworks incorporate horizons, geodesics, or curvature.

The present work synthesizes these disparate traditions into a unified geometric model of subjective time. By treating accumulated experience I(t) and future directed value λ(t) as coordinates on a 2-dimensional informational manifold, it is constructed an effective metric that governs the flow of subjective time. The metric exhibits curvature, horizons, and collapse phenomena analogous to those found in gravitational physics [20–22]. Life histories become geodesics in this manifold, shaped by informational entropy and motivational structure. Aging corresponds to an inward drift toward an informational horizon, where subjective time slows and eventually ceases. Legacy and memory emerge as informational radiation analogous to Hawking emission. This paper proposes a formal analogy between the dynamics of subjective time and gravitational time dilation in general relativity. To my knowledge, no prior work has combined a metric of subjective time, a holographic informational boundary, geodesic life trajectories, an entropy driven horizon structure, and a formal analogy to gravitational time dilation. This synthesis provides a new theoretical foundation for understanding subjective time, aging, and the structure of human life.

2. Informational State Space

The subjective experience of time is non uniform across the lifespan. Children perceive time as slow, adults experience acceleration, and elderly individuals often report that time "flies" [6,12]. These effects are robust across cultures and epochs, suggesting a structural origin rather than a cultural one [23]. General relativity provides a rigorous framework for understanding how time dilates in curved spacetime [20,22]. This paper explores the hypothesis that subjective time may be governed by an analogous geometry—one defined not by mass and curvature, but by information and entropy accumulated over a lifetime. The analogy is supported by work linking entropy, information, and gravity [13–16]. We define a 2-dimensional state space as follows:

- I(t): accumulated structured experience, related to memory density and informational entropy [10,11];
- λ(t): future directed value or motivational tension, consistent with theories of intrinsic motivation and novelty seeking [24,25].

The choice of two dimensions parallels the holographic principle, where a lower dimensional boundary encodes a higher dimensional bulk [17–19]. We introduce an informational potential:

$$\Psi(\mathrm{I},\lambda) = -\left(\alpha_I I(t)^{1/2} + \alpha_I \lambda(\mathrm{t})\right), \quad (1)$$

where $\alpha_I>0$ and α_λ calibrate the influence of past experience and future value. It is motivated by psychophysical scaling laws [10] and diminishing returns in experience accumulation. The structure mirrors the moment quality function used in cognitive models of time and value [26] (Tse 2013). The square root dependence on I(t) reflects diminishing returns of experience, consistent with psychophysical scaling and with the structure of the moment quality function previously defined. We define subjective time τ_{subj} through an effective metric: $ds_{bio}^2 = -\left(1+\beta\Psi(\mathrm{I},\lambda)\right)^2 dt^2$, yielding:

$$\frac{d\tau_{subj}}{dt} = 1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t}), \quad (2)$$

with $k_I=\beta\alpha_I$ and $k_\lambda=\beta\alpha_\lambda$. This is the direct analogue of gravitational time dilation: $\frac{d\tau}{dt} \approx 1 + \frac{\Phi_g}{c^2}$, [21,22]. Because with age I(t) increases, the factor multiplying *dt* shrinks, producing the universal acceleration of external time [5,6]. The condition:

$$1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t) = 0, \tag{3}$$

defines an informational event horizon. Crossing this boundary implies:

- subjective time ceases ($d\tau_{subj}=0$);
- external time appears infinitely fast;
- activity collapses;
- no behavioural control (u(t), see e.g. [25]) can restore normal temporal flow.

This corresponds to terminal cognitive decline and loss of temporal structure [27,28]. The interior region is the biographical black hole, analogous to the Schwarzschild interior [14,20]. This region corresponds to:

- terminal cognitive decline;
- severe burnout;
- the final phase of life.

The interior region is the biographical black hole, a domain of no return analogous to the Schwarzschild interior. Because I(t) grows monotonically across life, every human trajectory naturally moves inward toward the horizon. This explains:

- acceleration of subjective time [6];
- narrowing of cognitive flexibility [29];
- increasing difficulty escaping habitual patterns [30];
- final collapse of temporal experience [27].

This is structurally identical to a particle spiraling inward in a gravitational potential well [21].

3. Geodesics in the Informational State Space

We interpret individual life histories as geodesics in the informational state space (I,λ), under the effective metric that encodes subjective time dilation.

3.1. Effective Metric and Kinematics

One can start from the time component of the biographical metric

$$ds_{bio}^2 = -(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t))^2 dt^2, \tag{4}$$

and then make it explicit that the person also can travel in the internal coordinates (I,λ). A minimal extension is

$$ds_{bio}^2 = -\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)\right)^2 dt^2 + A dI(t)^2 + B d\lambda(t)^2, \tag{5}$$

where A>0, B>0 are scaling constants (or, more generally, functions of I,λ) that set the “stiffness” of motion in each direction. This is the simplest diagonal metric on the 3D manifold with coordinates (t,I,λ). Trajectories can be parametrized by subjective proper time τ_{subj}, so that the Lagrangian is

$$L = \frac{1}{2} g_{\mu\nu} \frac{dx^\mu}{d\tau} \frac{dx^\nu}{d\tau} = \frac{1}{2}\left[-\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)\right)^2 \dot{t}^2 + A\dot{I}(t)^2 + B\dot{\lambda}(t)^2\right], \tag{6}$$

with $\dot{z} \equiv dz/d\tau$. For time-like geodesics we impose the normalization 2L=–1, which fixes the relation between $\dot{t}$, $\dot{I(t)}$, and $\dot{\lambda(t)}$.

3.2. Interpretation of Geodesics

The equations for time-line geodesics result from the Euler–Lagrange equations as shown in the Appendix A. In the framework proposed:

- Natural aging trajectories correspond to geodesics with monotonically increasing I(τ), driven by the fact that real lives accumulate experience irreversibly.
- Stable life cycles (orbits) correspond to trajectories that remain in a bounded region of (I,λ), where the effective potential admits closed or quasi-closed paths. These are the cyclic biographies with alternating phases of exploration and consolidation.
- Inward spirals correspond to trajectories where the right-hand side of the energy balance grows as the denominator $\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)\right)^2$ shrinks, driving the system toward the horizon curve $1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t) = 0$
- Horizon-crossing paths are those for which no choice of initial conditions and no admissible control (later to be modelled as deviations from pure geodesic motion) can prevent the trajectory from reaching the horizon in finite τ_{subj}.

Thus, geodesics in (I,λ)-space provide the default, uncontrolled dynamics of a life history under the informational metric. Deviations from geodesicity (through control action u(t)) can be interpreted as intentional interventions—choices, therapies, structural changes—that push the trajectory away from collapse or out of stagnation.

Stable life cycles correspond to **orbits** in the (I,λ) plane:

- creative phases increase (I),
- integrative phases decrease (λ),
- the trajectory oscillates around a potential minimum.

These orbits can be shallow (broad, stable adult life) or deep (intense creative periods). Loss of novelty or excessive novelty can destabilize the orbit, leading either to stagnation or collapse. This matches psychological models of alternating exploration and consolidation [24,25].

4. Informational Curvature and Interpersonal Coupling

A central insight of general relativity is that mass–energy determines the curvature of spacetime, and curvature in turn governs the motion of bodies [20–22,31,32]. In the present model, an analogous relationship emerges: information determines the curvature of the biographical manifold, and this curvature shapes the flow of subjective time and the dynamics of life trajectories. This analogy extends naturally from individuals to interactions between individuals, where informational exchange produces coupling between their respective informational fields.

4.1. Curvature Generated by Informational Content

The biographical metric $ds_{bio}^2 = -\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)\right)^2 dt^2 + A dI(t)^2 + B d\lambda(t)^2$ encodes the influence of accumulated experience I and future-directed value λ on subjective time. As I increases or λ decreases, the time-dilation factor Φ(I,λ) = $(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t))$ shrinks, deepening the effective potential well and increasing the curvature of the informational manifold. This parallels the Einstein field equation $G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$ where curvature grows with mass–energy density. In the biographical setting, informational mass plays the role of energy density:

- high I(t) corresponds to a dense, compressed memory structure;
- low λ(t) corresponds to a narrowed future horizon;
- together they generate informational curvature that slows subjective time and draws trajectories inward.

A scalar measure of curvature can be defined phenomenologically as

$$R_{bio}(I,\lambda) = f(k_I I^{\frac{1}{2}} - k_\lambda \lambda) \quad , \qquad (7)$$

where f is a monotone increasing function. This captures the intuition that the deeper the informational well, the stronger the curvature of subjective time.

4.2. Interpersonal Coupling Through Information Exchange

Human interactions involve continuous exchange of structured information. In the present framework, such exchanges naturally induce coupling between individual informational manifolds.

Let each person a have their own coordinates (I_a,λ_a) and metric factor $\Phi_a = (1 - k_I I_a^{\frac{1}{2}} - k_\lambda \lambda_a)$. When two individuals interact, they exchange informational content. This modifies their informational masses and motivational openness:

$$I_a = F_a(self) + \sum_{b \neq a} C_{ab} J_{b \to a} \quad , \tag{8}$$

$$\lambda_a = G_a(self) + \sum_{b \neq a} D_{ab} J_{b \to a} \quad , \tag{9}$$

Here:

- $J_{b \to a}$ is the information flux from person b to person a,
- C_{ab} and D_{ab} are coupling coefficients,
- F_a and G_a describe self-driven learning, novelty, or decline.

Thus, interpersonal influence becomes curvature-mediated interaction: each individual's informational field affects the geometry of others' subjective time.

This provides a geometric interpretation of well-known psychological phenomena:

- inspiring individuals increase $\lambda(t)$ in others,
- traumatic interactions increase I(t) sharply and reduce $\lambda(t)$,
- long-term relationships produce mutual curvature shaping, social isolation reduces informational flux and accelerates inward drift.

4.3. Informons: Quanta of Informational Influence

In analogy with gravitons—the hypothetical quanta of the gravitational field—we may introduce informons as conceptual quanta of informational influence. An informon is a minimal unit of structured information exchanged between individuals that:

- increases I in the receiver,
- modifies λ (either expanding or contracting future possibilities),
- and thereby alters the local curvature of their biographical manifold.

Informons are not physical particles but conceptual quanta representing:

- a sentence;
- a gesture;
- a memory;
- a lesson;
- a trauma;
- a moment of inspiration.

Each informon slightly reshapes the informational geometry of both sender and receiver. Over time, the cumulative effect of informon exchange generates interpersonal gravitational fields—patterns of influence, attachment, mentorship, conflict, or resonance.

4.4. Collective Curvature and Social Fields

In groups, the superposition of many informational interactions produces collective curvature:

- communities with high informational flux maintain high λ and resist collapse,
- rigid or oppressive environments reduce λ and deepen curvature,
- creative networks generate outward "repulsive" regions enabling escape trajectories,
- social collapse corresponds to synchronized inward drift toward the horizon.

Thus, the model naturally extends from individuals to dyads, groups, and societies, offering a geometric language for:

- cultural transmission;
- collective memory;
- social ageing;
- and the dynamics of influence.

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5. Aging as Inward Motion Toward the Horizon

Aging is one of the most universal and robust features of human life trajectories. In the geometric model developed here, aging corresponds to a systematic inward drift in the informational state space (I,λ), driven by the monotonic accumulation of structured experience and the gradual reduction of cognitive flexibility. This section formalizes the connection between aging, geodesic motion, and the approach to the informational horizon.

5.1. Monotonic Growth of Informational Mass I(t)

The variable I(t) represents accumulated structured experience. Unlike many psychological variables, I(t) is irreversible: once experience is acquired, it cannot be "unlearned" in the sense of reducing informational density. Even memory loss does not reduce the underlying informational mass; it merely reduces access to it.

Mathematically, this implies: $\frac{dI}{dt} \geq 0$ with equality only in pathological or extreme late-life conditions. Under any reasonable behavioural control u(t), the system satisfies:

$$I(t) = I_0 + \int_0^t f(u(s))ds, \quad (10)$$

where f(u) is a novelty-dependent accumulation rate. This monotonicity ensures that the term $k_I I(t)^{1/2}$ in the metric grows steadily across the lifespan. As a consequence, the time-dilation factor $1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)$ shrinks with age, producing the universal acceleration of external time reported in psychological studies.

5.2. The Shrinking of Subjective Time

The subjective proper time satisfies: $\frac{d\tau_{subj}}{dt} = 1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)$. As I(t) increases, the right-hand side of this equation decreases. This yields three key predictions:

- Children (low I(t)) experience slow, expansive subjective time.
- Adults (moderate I(t)) experience moderate acceleration.
- Elderly individuals (high I(t)) experience rapid external time and compressed subjective time.

This matches empirical findings that temporal judgments compress with age, and that the older adults perceive years as passing more quickly. In geometric terms, the trajectory moves deeper into the potential well, where the metric increasingly dilates time.

5.3. Geodesic Drift Toward the Horizon

The effective potential $V_{eff}(I,\lambda)$ (Appendix A) shows that as the denominator shrinks, the effective potential steepens. This produces a geodesic drift toward the horizon curve: $1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t) = 0$. This drift is not caused by pathology but by the intrinsic geometry of the informational manifold. Even in the absence of external shocks or internal crises, the system naturally moves inward. This provides a geometric explanation for the phenomenology of aging:

- reduced novelty,
- narrowing of behavioural options,
- increasing predictability,
- compression of subjective time,
- and eventual collapse of temporal structure.

5.4. Loss of Cognitive Flexibility as Curvature

The variable $\lambda(t)$ represents future-directed value, motivation, and cognitive openness. Empirical research shows that:

- novelty seeking declines with age,
- future time perspective narrows,

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- motivational horizons contract.

In the model, this corresponds to a gradual reduction in $\lambda(t)$, which further increases the curvature of the metric:

$$g_{00} = -\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)\right)^2, \tag{11}$$

A decrease in $\lambda(t)$ accelerates the approach to the horizon. Thus, aging is not only the accumulation of experience but also the **loss of future-directed degrees of freedom**.

5.5. The Inevitability of Horizon Crossing

Because I(t) grows monotonically and $\lambda(t)$ tends to decline, the horizon condition $1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t) = 0$ is eventually satisfied for every trajectory. Crossing this boundary corresponds to:

- cessation of subjective time,
- collapse of agency,
- inability to track external events,
- and the phenomenological end of life.

This is the informational analogue of falling into a black hole. The collapse is not abrupt but the culmination of a long inward spiral.

5.6. Aging as a Geometric Inevitability

The model proposed predicts that:

- aging is not merely biological decay,
- nor merely cognitive decline,
- but a geometric consequence of informational accumulation.

The curvature of the informational manifold increases with I, and the geodesic flow naturally carries the system toward the horizon. This provides a unified explanation for:

- the acceleration of subjective time,
- the narrowing of cognitive horizons,
- the reduction of novelty,
- and the inevitability of temporal collapse.

In this sense, aging is the geodesic destiny of any informationally accumulating system.

5.7. Aging Modelling

Aging, in the model proposed, is the process by which:

- informational mass increases,
- temporal curvature deepens,
- subjective time slows,
- external time accelerates,
- and the system approaches its horizon.

This mirrors the behaviour of particles falling into gravitational wells, where:

- potential deepens,
- time dilates,
- escape becomes impossible,
- and the horizon is eventually crossed.

The analogy is not superficial but structural: both systems are governed by entropy, information, and geometric constraints. In General Relativity (GR), escape from a gravitational well requires velocity exceeding escape velocity. Inside the horizon, escape velocity exceeds the speed of light c making escape impossible [22,31,32]. In our model:

- escape requires a control effort u_{esc},
- but (u) is bounded: $(0 < u < 1)$,
- if $u_{esc} > 1$, escape is impossible.

This defines the biographical point of no return, analogous to the GR event horizon.

6. Entropy, Information, and the Holographic Interpretation

The informational state space (I,λ) is not merely a convenient abstraction. It plays a role analogous to the holographic boundary in gravitational physics, where lower-dimensional surfaces encode the dynamics of higher-dimensional systems. In this section, we develop the entropy-based interpretation of the model and show how subjective time, memory, and identity can be understood through holographic principles [18,19]. The analogy extends to entropy:

- in GR, horizons have entropy proportional to area [13,14];
- in cognition, accumulated experience increases informational entropy [11];
- subjective time dilation is tied to entropy density [10].

The two-dimensional (I,λ) surface acts as a holographic boundary encoding the full complexity of lived experience [18,19].

6.1. Entropy as the Driver of Temporal Geometry

In physical systems, entropy determines the direction of time and the curvature of spacetime near horizons [13–15]. In cognitive systems, entropy arises from:

- the accumulation of structured experience,
- the compression of memory representations,
- the reduction of novelty,
- and the increasing predictability of life events.

The variable I(t) can be interpreted as a cumulative entropy measure of lived experience. As I(t) increase the informational manifold becomes more curved, and the subjective flow of time slows: $\frac{d\tau_{subj}}{dt} = 1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t)$. This parallels gravitational time dilation, where increasing mass-energy density slows proper time.

Thus, subjective time is not simply a psychological illusion but a **geometric consequence of informational entropy**.

6.2. The Informational Boundary as a Holographic Surface

The model uses only two internal variables, I(t) and λ(t), to encode the entire temporal phenomenology of a human life. This is structurally similar to the holographic principle [17–19], where:

- a lower-dimensional boundary encodes the full dynamics of a higher-dimensional bulk,
- entropy is proportional to boundary area,
- and horizons act as informational limits.

In our model:

- the bulk is the full complexity of lived experience,
- the boundary is the 2D surface (I,λ),
- subjective time is determined entirely by this boundary,
- and the horizon is the limit where the boundary saturates.

This suggests that the human temporal experience is holographically encoded in a low-dimensional informational surface.

6.3. Memory Compression and Holographic Encoding

Human memory is not a literal archive of past events but a compressed, lossy representation optimized for prediction and coherence [10,11]. This compression is analogous to:

- holographic encoding of bulk information,
- coarse-graining near horizons,
- and entropy bounds on representable states.

As I(t) increases, memory becomes more compressed, and the effective "resolution" of subjective time decreases. This explains why:

- childhood memories are sparse but vivid;
- adult memories are dense but less distinct;
- late-life memories become highly compressed and temporally flattened.

The holographic analogy provides a natural explanation for these phenomena.

6.4. The Horizon as an Entropy Bound

The horizon condition $1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t) = 0$ marks the point where the informational boundary reaches its maximal entropy density. Beyond this point, the system cannot maintain a coherent temporal structure. This is analogous to:

- the Bekenstein bound on information storage,
- the maximal entropy of black hole horizons,
- and the breakdown of classical spacetime inside a black hole.

In cognitive terms, crossing the horizon corresponds to:

- collapse of temporal continuity,
- loss of activity,
- inability to track external events,
- and the phenomenological end of subjective time.

This is the informational singularity of a human life.

6.5. Future-Directed Value λ(t) as a Holographic "Radial" Coordinate

In gravitational holography, the radial coordinate encodes energy scale or renormalization flow. In our model, λ(t) plays a similar role:

- high λ(t) corresponds to openness, novelty, and future-directed motivation,
- low λ(t) corresponds to narrowing horizons and reduced cognitive flexibility.

As λ(t) decreases with age, the system moves "radially inward" toward the horizon. This provides a geometric interpretation of:

- reduced future time perspective,
- motivational narrowing,
- and the contraction of life possibilities.

Thus, λ(t) is the holographic analogue of the radial coordinate in AdS/CFT-like models [22,31,32].

6.6. Identity and Legacy as Hawking Radiation

In gravitational physics, black holes emit Hawking radiation, slowly releasing information back into the universe. In human terms, the analogue is:

- memories left in others,
- works, writings, and creations,
- social influence,
- cultural impact,
- and the informational traces that persist after subjective time ends.

These traces are the informational radiation of a life, emitted as the system approaches and crosses its horizon. They represent the outward flow of information from a collapsing informational manifold. This analogy is not poetic but structural: both processes involve the release of information from a system that has reached maximal entropy density.

6.7. A Holographic Theory of Subjective Time

The holographic interpretation provides a unified framework for understanding why:

- subjective time accelerates with age;

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- memory compresses;
- activity narrows;
- collapse is inevitable;
- informational traces persist after subjective time ends.

The informational manifold (I,λ) acts as a holographic boundary encoding the full temporal experience of a human life. Aging corresponds to the inward flow toward the horizon, and death corresponds to crossing it.

This positions the model within a broader theoretical landscape where:

- entropy drives temporal geometry;
- information determines curvature;
- and horizons mark the limits of representation.

7. Discussion

The geometric model of subjective time developed in this work yields a set of concrete predictions about human temporal experience, cognitive aging, and life-trajectory dynamics. These predictions arise from the structure of the informational metric, the behaviour of geodesics in (I,λ)-space, and the horizon condition that governs the collapse of subjective time.

7.1. Subjective Time Across the Lifespan

The model predicts a characteristic trajectory of subjective time dilation:

- Early life: Low I(t) and high λ(t) produce a large value of $\frac{d\tau_{subj}}{dt}$, corresponding to slow, expansive subjective time.
- Midlife: Moderate I(t) and declining λ(t) reduce the factor, producing the familiar acceleration of external time.
- Late life: High I(t) and low λ(t) push the system toward the horizon, where subjective time compresses dramatically.

This aligns with empirical findings that temporal judgments shorten with age and that the older adults perceive years as passing more quickly.

7.2. Cognitive Flexibility and Novelty

The model predicts that:

- novelty-seeking behaviour declines as λ(t) decreases;
- the ability to generate new trajectories in (I,λ)-space diminishes;
- interventions that increase λ(t) (e.g., new environments, learning, social engagement) temporarily “push” the trajectory outward.

This provides a geometric interpretation of why novelty-based interventions can slow subjective time and improve well-being.

7.3. Burnout and Collapse

Burnout corresponds to a rapid inward movement toward the horizon, driven by:

- excessive accumulation of structured experience without integration (high I(t));
- loss of future-directed value (low λ(t));
- and insufficient control u(t) to counteract the drift.

The model predicts:

- a threshold beyond which recovery becomes increasingly difficult;
- a point of no return where $u_{esc}>1$;
- and a collapse of subjective time as the horizon is approached.

This provides a unified geometric explanation for the phenomenology of burnout, depression, and late-life cognitive collapse.

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7.4. Life Cycles and Stable Orbits

The effective potential (Appendix A) implies the existence of:

- stable orbits, corresponding to balanced life cycles with alternating phases of exploration and consolidation;
- unstable orbits, where small perturbations lead to collapse or stagnation;
- escape trajectories, where high novelty and high λ allow temporary outward movement.

These predictions can be tested by analysing longitudinal data on life satisfaction, novelty engagement, and subjective time reports.

7.5. Horizon and End-of-Life Experience

The horizon condition $1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(t) = 0$ predicts that:

- subjective time approaches zero as the horizon is approached;
- external time appears increasingly fast;
- temporal continuity breaks down;
- the phenomenological end of life corresponds to crossing the horizon.

This provides a geometric interpretation of late-life temporal flattening, loss of activity, and the final collapse of subjective experience.

7.6. Psychology and Cognitive Science

The model suggests that:

- subjective time is fundamentally geometric rather than purely psychological;
- aging is driven by informational entropy rather than biological decay alone;
- cognitive decline is a curvature effect in the informational manifold;
- and interventions should target $\lambda(t)$ (future value) as much as I(t) (experience).

This reframes aging and burnout as geometric processes rather than merely biological or emotional ones.

7.7. The Philosophy of Time

The model supports a view in which:

- subjective time is emergent from informational structure;
- temporal flow is not fundamental but derived from entropy gradients;
- horizons mark the limits of representable experience;
- and identity is encoded holographically on a low-dimensional boundary.

This aligns with modern views in physics that treat time as emergent rather than fundamental.

7.8. Future Empirical Research

The model suggests several testable hypotheses:

- the rate of subjective time acceleration correlates with measures of memory density;
- novelty-based interventions increase $\lambda(t)$ and slow subjective time;
- burnout corresponds to trajectories approaching the horizon;
- and late-life temporal flattening corresponds to the final inward drift.

These predictions can be evaluated using longitudinal psychological data, neurocognitive measures, and subjective time reports.

The model suggests several avenues for further research:

- deriving geodesic equations in (I, λ)-space;
- identifying stable and unstable trajectories;
- modelling interventions that shift geodesics;
- calibrating parameters using empirical data on aging and cognition;
- exploring analogues of Hawking radiation (informational legacy).

The inevitability of collapse does not trivialize the model; it mirrors the structure of physical cosmology and provides a unified geometric understanding of human temporal experience.

5. Conclusions

The geometric model developed in this work provides a unified framework for understanding subjective time, aging, and the structure of human life trajectories. By treating accumulated experience (I(t)) and future-directed value (λ(t)) as coordinates on an informational manifold, it was constructed an effective metric that governs the flow of subjective time. This metric exhibits horizons, curvature, and collapse phenomena analogous to those found in gravitational physics. The model explains why:

- subjective time accelerates with age;
- cognitive flexibility declines;
- burnout and collapse occur;
- the end of life corresponds to a horizon crossing.

The analogy with gravitational time dilation is not superficial but structural: both systems are governed by entropy, information, and geometric constraints. The holographic interpretation suggests that the full complexity of lived experience is encoded on a low-dimensional informational boundary, and that identity and legacy persist as informational radiation beyond the horizon.

This framework opens new avenues for theoretical, empirical, and philosophical exploration. The next steps involve deriving the full geodesic equations, analyzing stability conditions, and calibrating the model with empirical data. The ultimate goal is a comprehensive geometric theory of subjective time that integrates psychology, physics, and information theory into a coherent whole.

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Abbreviations

The following notation and conventions are used throughout the paper:

- t — External, physical time measured by clocks. This is the independent variable for life-course evolution.
- τ_{subj} — Subjective proper time experienced by the individual. It is defined through the biographical metric and satisfies $d\tau_{subj} \leq dt$.
- $\dot{x}$ — Derivative with respect to subjective proper time: $\dot{x} = dx/d\tau_{subj}$
- I(t) — Accumulated structured experience or informational mass which is monotonically non-decreasing dI/dt≥0 and represents memory density, informational entropy, and the compression of lived experience.
- λ(t) — Future-directed value, motivational openness, or cognitive flexibility which declines with age in typical trajectories but may fluctuate due to novelty, learning, or interventions.
- $\Psi(I,\lambda)$ — Effective informational potential shaping subjective time.
- k_I, $k_\lambda>0$ determine the strength of informational curvature.
- A, B>0 set the stiffness of motion in the I and λ directions.
- The Lagrangian for geodesic motion is: $L = \frac{1}{2} g_{\mu\nu}\dot{x}^\mu \dot{x}^\nu$.
- The normalization condition for time-like curves is: $g_{\mu\nu}\dot{x}^\mu \dot{x}^\nu = -1$.
- u(t) — Behavioural or cognitive control effort, representing intentional deviation from geodesic motion which is bounded: $0 \leq u(t) \leq 1$.
- The model is phenomenological: constants α_I, α_λ, k_I, k_λ, A, B are to be calibrated empirically.

Appendix A

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The geodesic equations follow from the Euler–Lagrange equations

$$\frac{d}{d\tau}\left(\frac{\partial L}{\partial \dot{x}^{\mu}}\right) - \frac{\partial L}{\partial x^{\mu}} = 0, x^{\mu} \in \{t, I, \lambda\}$$

Because the metric is stationary (has no explicit t-dependence), the conjugate momentum to t is conserved:

$$p_t = \frac{\partial L}{\partial \dot{t}} = -\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2 \dot{t} \quad = -E$$

where E>0 is a constant of motion. Thus

$$\dot{t} = \frac{E}{\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2}$$

Substituting into the normalization condition $-\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2 \dot{t}^2 + AI(\dot{t})^2 + B\lambda(\dot{t})^2 = -1$ we obtain an effective "energy balance": $AI(\dot{t})^2 + B\lambda(\dot{t})^2 = \frac{E^2}{\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2} - 1$. This has the form (kinetic in I,λ)=(effective energy)−(effective potential), with the **effective potential**

$$V_{eff}(I, \lambda) = 1 - \frac{E^2}{\left(1 - k_I(t) I^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2}$$

The remaining Euler–Lagrange equations for I(t) and λ(t) are

$$\frac{d}{d\tau}\left(A\dot{I}(t)\right) + \frac{\partial}{\partial I}\left[\frac{1}{2}\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2 \dot{t}^2\right] = 0$$

$$\frac{d}{d\tau}\left(B\dot{\lambda}(t)\right) + \frac{\partial}{\partial \lambda}\left[\frac{1}{2}\left(1 - k_I I(t)^{\frac{1}{2}} - k_\lambda \lambda(\mathrm{t})\right)^2 \dot{t}^2\right] = 0$$

Using t˙ from above, these become explicit second-order ordinary differential equations for I(τ) and λ(τ). In practice, for qualitative analysis, the effective-potential form is often more transparent than the full second-order system.

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