Experienced Duration as an Organizer of Biological Unfolding: The Internal Duration Setting Heuristic

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Abstract

Biological change is conventionally measured across objective time, yet elapsed time does not explain how a condition is experienced, retained, projected, or biologically expressed. This monograph introduces Internal Duration Setting (IDS), a heuristic proposing that experienced duration may participate in organizing biological unfolding. IDS distinguishes time as a standardized measure from duration as the qualitative continuity through which embodied, cognitive, emotional, and contextual processes coemerge.

The framework differentiates experienced duration during an event from Retrospective Duration Estimate and Prospective Duration Projection. Archive Density and Archive Loading describe how contextual differentiation and integration make an experience durationally available during retrieval. Temporal Boundary Expectation identifies how an anticipated transition can organize an embodied response before the expected boundary is reached. Experimental findings involving glucose regulation, pain, memory, interoception, and temporal expectation provide convergent

domains through which these distinctions are developed without treating perceived time as a sufficient causal explanation.

The monograph extends IDS to relational terrains, proposing that Gratitude as Graceful Receiving and Generosity as Graceful Offering may generate reciprocal conditions of high Archive Density and expansive future duration. Preliminary findings from the Centenarian Consciousness Index and GlycanAge are considered within Compensatory Complexity: the coordination of processes that may reduce the damaging expression of biological burden without reversing entropy or eliminating inflammaging.

IDS remains a testable heuristic rather than an established biological mechanism. Its scientific value depends on whether its constructs can be operationalized independently and explain biological variation beyond objective duration, attention, memory, affect, expectancy, health behavior, and established physiological predictors.

Keywords: Internal Duration Setting; experienced duration; biological unfolding; Archive Loading; Retrospective Duration Estimate; Prospective Duration Projection; temporal expectation; Compensatory Complexity

Introduction

Biological change is ordinarily described in relation to time. Metabolic variation, neural activity, inflammatory response, pain, healing, and aging are measured across seconds, minutes, years, or lifetimes. This use of time is indispensable for locating change, comparing rates, and establishing experimental sequences. Yet the precision of temporal measurement can obscure an epistemological distinction: time identifies the measurable interval across which change occurs, but it does not explain the duration through which a biological condition is lived and unfolds.

Treating time as the explanation for change risks converting the measure into the constituent presumed to produce what it measures (Martinez, 2026).

Contemporary research increasingly indicates that experienced duration is not an internal reproduction of clock time. Prospective and retrospective judgments vary with interoception, bodily state, attention, emotion, sensorimotor activity, and memory. These findings establish duration as embodied and context-dependent, although it continues to be investigated primarily as a problem of temporal perception or estimation (Teghil, 2024). The organism does not merely register an invariant temporal passage differently; the interval is experientially organized through the conditions in which it is lived.

This distinction opens the present inquiry. If duration emerges through the coemergence of embodiment, cognition, emotion, memory, and contextual meaning, its function may extend beyond estimating time. It may participate in organizing how biological processes develop, persist, and change. The central question is therefore not only why time seems to pass differently, but whether biological unfolding is partly organized by the duration the organism is experiencing.

Time as Measure, Duration as Constituent

A clock establishes correspondence between a process and a standardized sequence of change. It permits the interval between observations to be quantified and rates obtained under different conditions to be compared. What it records, however, is not the condition itself. Metabolic regulation, nociceptive activation, anticipation, recovery, boredom, discovery, and sleep can occupy equivalent clock intervals without constituting equivalent lived durations.

The distinction is not between objective time and an inaccurate subjective version of it. Time and duration perform different epistemological functions. Time provides the measure by which change is located and compared. Duration is the continuity of the unfolding process that makes such

comparison possible. A clock does not create that continuity; it indexes change occurring within it.

Evidence that bodily activity participates in temporal experience makes this distinction increasingly relevant. Perceived duration has been shown to expand and contract across phases of a single heartbeat, indicating that even brief duration judgments are dynamically coupled with physiological activity (Arslanova et al., 2023). Electrophysiological research has also identified coordinated brain–heart activity during temporal estimation, supporting an embodied rather than exclusively cognitive account of experienced duration (Khoshnoud et al., 2024). These findings establish bodily participation in temporal experience; they do not, by themselves, demonstrate that experienced duration organizes biological change.

The Internal Duration Setting heuristic begins at that evidentiary boundary. Duration is constituent because biological unfolding cannot occur without continuity. Experienced duration is the qualitative organization of that continuity through the coemergence of biological, perceptual, emotional, and contextual processes. Time can measure differences in the resulting change, but measurement alone cannot identify how the condition was internally organized.

This preserves the scientific function of time while opening a vertical question: when equivalent clock intervals yield different experiential or biological outcomes, what durational organization contributed to the difference?

Internal Duration Setting: The Qualitative Organization of Experienced Duration

Movement, interoception, sensory conditions, and neural activity can alter temporal experience. Slowing bodily movement can slow perceived duration, while eyes-open and eyes-closed timing can recruit different cortical systems despite producing nearly identical estimates (De Kock et al.,

2021; Proshina et al., 2024). These findings demonstrate that temporal experience changes with the condition in which it occurs. They do not identify the organization from which those changes emerge.

Internal Duration Setting introduces that vertical distinction. **Fast–slow** identifies the experienced rate of duration; **expansive–constrictive** identifies the horizon of possibility available within it. These dimensions are not endpoints of description but entrances into the terrain of meaning organizing the condition.

Two people may experience duration as fast while inhabiting different terrains: one may be organized by curiosity and expanding possibility, the other by urgency and option collapse. Conversely, slow duration may express contemplative openness or immobilizing constriction. Experienced rate alone does not reveal its organizing meaning.

IDS therefore moves inquiry from the behavior of a terrain to the terrain itself. Observable behavior, response latency, and temporal estimates express how a condition is unfolding, but they do not disclose the contextual organization that makes those expressions available. A rapid response may emerge from decisiveness within an expansive horizon or from urgency within a constricted one. The measured behavior can be similar while its durational organization is fundamentally different.

The vertical function of IDS is to identify the relationship among experienced rate, available horizon, and terrain of meaning. The relevant question is not merely whether duration feels fast or slow, but what contextual organization makes that rate coherent and what possibilities it permits or excludes. At this level, experienced duration becomes available as a biological hypothesis because it is not treated as an isolated perception. It is the lived expression of an organization in which embodiment, cognition, emotion, and contextual meaning are already participating.

This architecture permits similar observable outcomes to be examined as expressions of different durational organizations.

From Horizontal Findings to IDS Verticality

Experimental research ordinarily proceeds horizontally. A condition is manipulated, an outcome is measured, and differences between conditions are evaluated. When adequately controlled, this establishes that the manipulation contributed to the measured effect. Horizontal inquiry is indispensable because it determines whether a relationship exists and protects interpretation from uncontrolled inference.

The limitation that concerns IDS is explanatory rather than experimental. If a biological response changes with experimentally manipulated perceived time, the finding establishes a relationship between the manipulation and the outcome. However, concluding that perceived time caused the response restates that relationship without explaining how the altered temporal experience entered biological regulation. Manipulation checks may confirm that participants experienced different durations; they do not identify the organization through which those differences became biologically consequential.

IDS verticality begins at this unresolved level. It does not replace the experimental variable or reinterpret the outcome as something other than what was measured. It changes the unit of inquiry from the named variable to the organization through which that variable acquired biological relevance. “Perceived time” is no longer treated as an indivisible cause. It becomes an entry point into the embodied, cognitive, emotional, and contextual relations constituting experienced duration.

This movement follows a biocognitive epistemology in which knowing is not produced by a detached mind representing an independent biological object. The knower, the process of knowing,

and the condition known participate recursively in the formation of the observation (Martinez, 2001). Varela's neurophenomenological method similarly proposed that disciplined accounts of lived experience and biological measurement should constrain and inform one another rather than remain separate explanatory domains (Varela, 1996).

IDS extends this reciprocity by asking how a measured difference emerged from a particular durational organization. Inquiry moves from the outcome to the relations constituting experienced duration, and from those relations to the terrain of meaning that made the condition coherent. The original finding remains intact. Verticality adds explanatory depth without claiming that one level invalidates another.

This method also establishes an evidentiary boundary. IDS interpretations must remain heuristic when the proposed organization was not directly measured. Their function is to generate more discriminating questions and testable designs, not to retrospectively declare an unmeasured mechanism. Verticality is therefore neither reduction nor unconstrained speculation. It is the disciplined identification of what a finding establishes, what it leaves unexplained, and what additional inquiry is required.

Prospective and Retrospective Duration

The distinction between prospective and retrospective timing is usually defined by whether participants know in advance that they will estimate an interval. In prospective tasks, attention can be allocated to temporal passage while the event is occurring. In retrospective tasks, duration is assessed unexpectedly after the event and reconstructed from what remains available in memory. These procedures do not access the same temporal process through different methods; they establish different epistemological conditions.

IDS requires a further distinction. **Experienced duration** refers to how a condition is lived while it unfolds, whether or not the person expects to estimate it. **Retrospective Duration Estimate (RDE)** is the later judgment of how much duration passed. RDE is not a direct recovery of experienced duration. It is a new construction produced within the conditions of retrieval.

Recent evidence demonstrates the importance of this separation. Yue et al. (2026) found that retrospective duration judgments of naturalistic events depended on recalled event structure. Estimates of whole events were influenced by the number of remembered subevents, whereas estimates of individual subevents were more closely related to recalled gist and detail. Reported duration therefore varied with the hierarchical organization of memory rather than functioning as retrieval of an independently stored temporal quantity.

The reconstructive process can remain open after the event has ended. Ono (2024) demonstrated that directing attention to different features of an identical visual display after its disappearance altered judgments of how long the display had been present. Retrospective duration was therefore reorganized by an attentional condition introduced after the measured interval was complete.

Vertically, these findings indicate that an event has at least two distinguishable durational organizations. The first is the duration lived while the condition unfolds. The second is the duration constructed when the event is retrieved. RDE emerges through the interaction between the archived organization of the event and the contextual conditions of recall. It should not be treated as a transparent report of either clock time or original experienced

duration. The unresolved variable is what makes an archived experience durationally rich or sparse.

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Archive Loading and Durational Reversal

If retrospective duration is constructed from what becomes available during retrieval, the vertical question is how an experience acquires durational weight. Counting remembered details is insufficient because recollection is hierarchically organized. A few contextually decisive transitions may differentiate an experience more strongly than numerous disconnected elements. The relevant unit is not memory quantity alone, but the organization of what becomes retrievable.

Archive Loading identifies the total durationally available archive generated by an experience. **Archive Density** identifies the degree of contextual integration among the elements within that

archive. An experience may contain numerous remembered details while remaining low in density if those details lack meaningful relation. Conversely, a small number of contextually integrated transitions may produce substantial durational weight.

Novelty, salience, event boundaries, embodiment, and contextual meaning can increase Archive Loading by generating distinguishable and retrievable relations. Archive Density increases when those relations qualify one another within a coherent terrain. Repetition without meaningful differentiation may produce substantial exposure while leaving a comparatively sparse archive.

Recent findings provide a biological correlate for this distinction. Morrow et al. (2026) found that contextual transitions were associated with ventral tegmental area activity and increased blinking—indirect markers related to dopaminergic processing. Stronger responses at event boundaries predicted greater remembered temporal distance between objectively equidistant items. The imaging and eye-tracking findings do not directly demonstrate dopamine release, but they indicate that the biological processing of contextual change participates in how duration is subsequently reconstructed.

Memorability and experienced duration may also influence one another during encoding. Ma et al. (2024) found that more memorable images were judged as having been presented for longer and that images experienced as lasting longer were more likely to be remembered the following day. The relationship was reciprocal rather than a simple sequence in which temporal judgment followed completed memory formation.

IDS extends these findings from encoded quantity to contextual quality. High Archive Loading occurs when an experience generates sufficient differentiation and integration to remain durationally available. Low Archive Loading occurs when an interval leaves few retrievable relations, even if the condition felt prolonged while it was occurring. Archive Loading is therefore

not a synonym for good memory. It identifies what the archive makes available for durational reconstruction.

This distinction clarifies **durational reversal**. An engaging condition may be lived as fast because attention participates in the experience rather than monitoring its passage. If the condition produces high Archive Loading, it may later be estimated as comparatively long. A boring condition may be lived as slow because attention repeatedly returns to its continuation, yet later appear short when its sparse archive provides little internal differentiation. This reversal is not universal: threat, trauma, emotional intensity, and disrupted encoding can reorganize both ongoing duration and subsequent recall.

Experienced rate and remembered extent are therefore not opposing reports of the same temporal object. They emerge from different durational conditions. Experienced rate expresses how duration was lived; remembered extent expresses what the archive makes durationally available. Archive Density contributes to the weight of that archive, while Archive Loading identifies what becomes available to RDE.

Experienced Duration and Biological Unfolding

Biological measurements are usually treated as observations made at successive points in objective time. IDS introduces a different question: could a biological value measured at the end of an interval represent the accumulated effect of an interaction between experienced duration and biology? Biological unfolding, in this formulation, is not merely a sequence occurring during clock time. Its rate, intensity, or organization may be influenced by how duration is constituted within the organism.

Park and colleagues provided a direct experimental opening for this question. Forty-six participants with type 2 diabetes completed a task lasting ninety minutes while viewing a clock

that appeared to run at half speed, normal speed, or twice normal speed. Although objective duration was identical across conditions, blood glucose declined in correspondence with the amount of time participants believed had elapsed. The slow-clock condition produced the smallest reduction, and the fast-clock condition produced the largest. The magnitude of glucose change also correlated with participants' estimates of elapsed time (Park et al., 2016).

The experiment establishes that manipulating temporal information can alter glucose regulation within the conditions studied. Yet *perceived time* remains a descriptive variable rather than an explanation of how the effect was organized. Saying that glucose changed because time was perceived differently identifies the experimental relationship without explaining how altered temporal experience entered metabolic regulation.

IDS proposes that the clock manipulation altered the experienced duration assigned to the metabolic interval. The fast clock did not add biochemical minutes. It organized the interval as though more metabolic activity should already have unfolded. This interpretation was not directly measured in the experiment; it identifies the additional level that an IDS-informed design would need to test.

The final glucose measurement can therefore be approached heuristically as the accumulated biological expression of what occurred while that duration was being experienced. In canonical IDS terms, **experienced duration influenced biological unfolding**.

A subsequent experiment extended the finding from elapsed duration to the contextual meaning of what was being metabolized. Thirty participants with type 2 diabetes consumed beverages containing identical amounts of sugar but labeled as containing either substantially less or more sugar. Their glucose trajectories corresponded more closely to believed sugar content than to the

identical material content of the beverages. Perceived sugar and nutritional satisfaction partially mediated the effect (Park et al., 2020).

Together, these studies identify two informational conditions entering glucose regulation: how long metabolism was believed to have been occurring and what was believed to be metabolized. IDS does not interpret these results as disembodied belief overriding physiology. Belief, temporal context, metabolic activity, and biological response formed a contextual event within which glucose regulation unfolded. The studies establish the effects; IDS identifies the durational organization as a candidate for further measurement.

Experimental pain provides an independent point of convergence. Pomares and colleagues held the intensity and objective duration of a thermal stimulus constant while manipulating its apparent duration through altered clock feedback. Pain ratings were lower when the clock represented the stimulus as shorter (Pomares et al., 2011). Maia and colleagues subsequently found that a comparable temporal illusion altered both reproduced duration and reported pain intensity during an objectively identical thermal stimulus (Maia et al., 2023).

These pain studies do not establish a specific molecular pathway, nor does a change in reported pain demonstrate an equivalent change in nociceptive activity. They establish something more precise: an identical physical stimulus was experienced differently when its apparent duration was organized differently. Pain was therefore not determined by stimulus intensity and objective duration alone.

The glucose and pain experiments involve different systems and endpoints, but they share a common structure. Objective duration or material input was held constant; the experienced or contextually represented condition changed; and the resulting response changed with it. The convergent inference is not that duration acts as an independent biological substance. It is that

biological and embodied processes unfold within a durational organization that can become consequential to their expression.

IDS thus converts *perceived time* from a terminal explanation into a researchable intermediate organization. The resulting question is no longer only whether perceived time matters, but how durational organization enters the unfolding response.

Anticipated Duration and Temporal Boundary Expectation

Expectancy research commonly investigates the anticipated direction or magnitude of an outcome: whether pain will increase or decrease, and whether a treatment will have a weak or strong effect. The temporal dimension has received less attention. An expected outcome also carries an anticipated interval before its arrival. IDS identifies this interval as **anticipated duration**: the lived duration through which the organism approaches an expected change.

Within anticipated duration, **Temporal Boundary Expectation** identifies the point at which the expected condition is believed to begin, end, or change. A temporal boundary is more than a clock designation. It partitions the future into *before the expected change* and *after the expected change*. The organism does not simply wait for that boundary; ongoing experience is organized in relation to it.

Camerone, Piedimonte, and colleagues investigated this organization in 166 healthy volunteers using an inert cream and electrically induced pain. Participants were told that the cream would reduce or amplify pain after 5, 15, or 30 minutes. Pain was assessed before application and at 10, 20, and 35 minutes afterward. Analgesic and hyperalgesic responses emerged at the first assessment following the assigned onset boundary, but not at assessments preceding it. Once initiated, analgesia remained relatively stable, whereas hyperalgesia continued to increase (Camerone, Piedimonte, et al., 2021).

The significance extends beyond the observation that expectations influence pain. The relevant groups received the same inert intervention, while the anticipated direction and onset of its effect differed. The response corresponded not only to whether pain was expected to decrease or increase but also to the assigned temporal boundary.

A second experiment tested whether temporal boundary expectation would extend to sustained, high-intensity pain. Fifty-three healthy participants received an inert cream before completing repeated cold pressor tests. One group was told that analgesia would begin after 5 minutes, another after 30 minutes, and a control group was told only that the cream was hydrating. At the 10-minute assessment, increased pain tolerance appeared only in the group expecting the early effect. At 35 minutes, increased tolerance was present in both expectancy groups: it had been maintained in the 5-minute group and had emerged in the 30-minute group. Heart-rate differences between groups were not significant (Camerone, Wiech, et al., 2021).

The absence of a corresponding heart-rate difference is an important evidentiary boundary. The study demonstrates temporally organized changes in pain tolerance, but it does not establish that every physiological system was reorganized by the temporal suggestion. The observable pain response corresponded to when analgesia was expected to become available.

The vertical contribution of IDS is to distinguish the temporal cue from the durational organization it may initiate. The phrases *after 5 minutes* and *after 30 minutes* supplied clock information. The cue also established a future transition toward which ongoing duration could be organized. That organization was not measured directly, but it can be separated operationally from both the cue and the resulting response.

The sequence contains four distinguishable components:

1. **Temporal information** specifies when a change is expected.

2. **Temporal Boundary Expectation** identifies the expected point of transition.
3. **Anticipated duration** is the lived interval through which the organism approaches that boundary.
4. **Response transition** is the measurable change emerging at or around the expected boundary.

Collapsing these components into the single construct of expectation obscures their different functions. Temporal information is introduced by the researcher; the expected boundary partitions the interval; anticipated duration is constituted by the participant; and the response transition is measured. This separation permits investigation of whether the qualities of the anticipatory interval predict the magnitude, latency, or persistence of the response.

Temporal boundaries also need not function symmetrically. An approaching analgesic boundary may organize the interval as movement toward relief, whereas an approaching hyperalgesic boundary may organize it as movement toward intensification. The clock interval can remain identical while durational orientation differs according to the meaning attributed to what is expected at its end. The function of Temporal Boundary Expectation therefore depends on both when the transition is expected and what that transition means within the contextual terrain.

The Camerone studies did not directly measure the phenomenological qualities of anticipated duration. They establish that the timing of pain-related responses can correspond to an experimentally assigned temporal expectation. IDS adds a testable level: the assigned boundary may become consequential through the experienced duration generated in approaching it. This remains a heuristic proposition until anticipated duration is measured concurrently with the response.

Prospective Duration Projection

Expectancy research commonly investigates the anticipated direction or magnitude of an outcome: whether pain will increase or decrease, and whether a treatment will have a weak or strong effect. The temporal dimension has received less attention. An expected outcome also carries an anticipated interval before its arrival. IDS identifies this interval as **anticipated duration**: the lived duration through which the organism approaches an expected change.

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Relational Terrains and Neuroimmune Regulation

Within IDS, Gratitude and Generosity are especially relevant because they organize reciprocal relations between receiving and offering.

Gratitude as Graceful Receiving is not merely acknowledgment that something beneficial occurred. It permits value originating outside the self to be received without indebtedness, diminishment, or defensive rejection. **Generosity as Graceful Offering** permits value to move

toward another without coercion, depletion, or required repayment. Their reciprocity forms a relational terrain expressed as:

Graceful Receiving ↔ Graceful Offering

The bidirectional relation is more consequential than either factor considered independently. Receiving without the capacity to offer may remain passive or indebted. Offering without the capacity to receive may become self-erasing, controlling, or dependent on recognition. When both are available, value can circulate without being organized by scarcity.

This reciprocity gives a relational event high potential for Archive Loading. An exchange can simultaneously contain recognition of value, emotional salience, self–other relevance, contextual meaning, embodied response, and future reciprocity. These dimensions are not merely accumulated details. They qualify one another, increasing the Archive Density of the experience.

IDS proposes the following durational pathway:

1. **Graceful Receiving ↔ Graceful Offering** creates a reciprocal terrain of value.
2. The relational event acquires Archive Density through emotional, embodied, interpersonal, and contextual integration.
3. Archive Density increases the event's potential Archive Loading.
4. Greater Archive Loading provides more material for Retrospective Duration Estimate.
5. Recurrent retrospective expansion can inform Prospective Duration Projection.

The heuristic does not claim that every grateful or generous act will be remembered as long, or that Archive Loading can be inferred from the moral desirability of an action. A socially expected act of giving may have little contextual meaning. A brief, culturally inconspicuous exchange may reorganize an entire relational terrain. Archive Loading depends on constituted meaning rather than behavioral appearance.

The distinction between **terrain of meaning** and **behavior of the terrain of meaning** is therefore essential. Offering assistance is observable behavior; Generosity is the terrain from which the offering acquires its organization. Saying thank you is observable behavior; Gratitude is the terrain organizing whether receiving is experienced as graceful, indebted, threatening, or undeserved. Similar behaviors can emerge from different terrains and carry different durational and biological implications.

Psychoneuroimmunology provides evidence that relational experience can participate in biological regulation, although the pathways are neither singular nor fully established. In a randomized six-week study, a gratitude-writing intervention increased reported support-giving but did not produce significant between-group differences in inflammatory markers. Across the full sample, however, increases in support-giving were associated with decreases in inflammatory measures (Moieni et al., 2019).

A subsequent analysis of related data found that greater increases in support-giving were associated with reduced amygdala reactivity during a gratitude task. Reduced amygdala reactivity was, in turn, associated with reductions in stimulated production of tumor necrosis factor-α and interleukin-6. The gratitude intervention did not produce significant between-group differences in the targeted neural responses. The mediation findings identify a plausible threat-regulation pathway without establishing a direct effect of gratitude on inflammation (Hazlett et al., 2021).

Evidence for the biological relevance of giving also comes from two independent observational samples. Giving support to more social targets and giving support more frequently were associated with lower circulating interleukin-6 after adjustment for relevant covariates. The association did not extend to C-reactive protein, and the cross-sectional design could not establish causality

(Inagaki et al., 2023). Relational offering may therefore correspond to particular inflammatory processes without producing a generalized anti-inflammatory state.

Oxytocin offers another possible pathway, but it should not be treated as a biochemical synonym for Gratitude or Generosity. Oxytocin participates in social attachment, stress regulation, and immune signaling, yet its effects depend on sex, relational context, tissue, timing, and the immune marker measured. In a randomized study of 80 couples, intranasal oxytocin and instructed positive interaction produced differing effects across wound cytokines, while observed friendliness in women was associated with lower local tumor necrosis factor-α. The results were context- and sex-specific rather than uniformly anti-inflammatory (Ditzen et al., 2023).

The evidence does not support the simple sequence:

Gratitude or Generosity → oxytocin → reduced inflammation

It supports a more differentiated formulation:

relational terrain → contextual appraisal and relational action → altered threat, caregiving, autonomic, endocrine, and immune regulation

Oxytocin may participate in this organization, but it is one component of a distributed neuroimmune process. The complete pathway from Graceful Receiving and Graceful Offering to inflammatory regulation has not been experimentally demonstrated.

IDS introduces a variable these studies did not measure: the duration constituted within the relational terrain. The same relational event may organize both neuroimmune regulation and Archive Loading. These effects may occur in parallel, experienced duration may partially mediate their relation, or both may emerge recursively from the same terrain. Current findings cannot distinguish among these possibilities.

An operational investigation would measure several levels within the same design:

1. **Relational terrain:** the participant's orientation toward Graceful Receiving and Graceful Offering.
2. **Event constitution:** contextual meaning, self–other referent, and perceived reciprocity.
3. **Durational organization:** experienced duration during the event, Archive Density, Archive Loading, and Retrospective Duration Estimate afterward.
4. **Neuroregulatory response:** threat-related neural activity, autonomic measures, or caregiving-system activation.
5. **Immune expression:** selected inflammatory markers measured at biologically appropriate response intervals.
6. **Prospective projection:** subsequent change in the experienced availability and pace of future duration.

This architecture would permit testing whether the reciprocal terrain produces effects that neither factor generates independently. A factorial design could compare receiving, offering, reciprocal exchange, and a relationally neutral control. The primary IDS prediction is not that reciprocity merely produces more positive emotion. It is that **Graceful Receiving ↔ Graceful Offering produces greater Archive Density, higher Archive Loading, and a more expansive Prospective Duration Projection than either unidirectional condition alone**.

Neuroimmune measures could then test whether this durational organization co-occurs with reduced threat signaling or differentiated inflammatory regulation. Mediation should not be assumed. The design must determine whether experienced duration participates in organizing the biological effect, whether both emerge from the relational terrain, or whether their relation is recursive.

Centenarian Time Expansion and Compensatory Complexity

To our knowledge, the **Centenarian Consciousness Index™ (CCI™)** is the first psychometric assessment derived from ethnographic content analysis of healthy centenarians across cultures. Its purpose is to identify recurrent perceptual and emotional terrain invariances, translate them into measurable factors, and examine their biological relevance through psychoneuroimmunological research and markers of biological aging (Martinez, 2025).

The CCI did not begin with a personality theory subsequently applied to centenarians. Its construction moved in the opposite direction. More than two decades of ethnographic observation, interviews, and content analysis provided the source material from which its factors were derived. The resulting items assess the orientation of those factors rather than conformity to conventional standards of successful aging.

The CCI organizes eight factors into two interdependent domains.

Perceptual factors

- **Time:** Experienced Duration
- **Aging:** Cultural Aging Consciousness
- **Health:** Learned Health Consciousness
- **Self-Valuation:** A Path to Personal Excellence

Emotional factors

- **Gratitude:** Graceful Receiving
- **Generosity:** Graceful Offering
- **Admiration:** Recognizing Laudable Qualities
- **Curiosity:** Inquisitiveness

These factors are not isolated personality traits. A CCI score identifies the current orientation of a terrain of meaning; it does not measure how often a participant performs a socially recognizable

behavior. A high Generosity orientation, for example, cannot be inferred from donations, volunteering, or compliance with expectations of helpfulness. It identifies how offering is constituted within the relational terrain. Verbal expressions of thanks likewise do not establish a capacity for Graceful Receiving.

Terrain invariance identifies an orientation that remains recognizable across changing conditions without requiring identical behavior. Cross-cultural invariance does not imply that centenarians express Gratitude, Generosity, or Time through uniform customs. It indicates that beneath culturally different expressions, a recurrent organization of meaning can be identified.

The PNI literature is applied after the factors are derived rather than used as their ethnographic source. Once a terrain invariance has been identified, relevant research is examined to determine whether its orientation is consistent with established neural, endocrine, autonomic, and immune pathways. This sequence protects the CCI from circular construction:

centenarian ethnography → terrain invariance → psychometric factor → PNI plausibility → biological correlation

CCI–GlycanAge Correlation

GlycanAge estimates biological age from age-associated patterns in immunoglobulin G glycosylation. IgG glycosylation participates in regulating antibody inflammatory activity and changes substantially with chronological age. In an analysis of 5,117 individuals, a composite of three IgG glycans explained up to 58% of chronological-age variance, while the remaining variance was associated with physiological characteristics relevant to biological aging (Krištić et al., 2014).

GlycanAge does not measure the totality of biological aging. It provides an immune-related estimate with particular relevance to inflammatory regulation. This makes it appropriate for the

present inquiry without permitting it to be treated as a complete measure of health, longevity, or organismic age.

The CCI–GlycanAge pilot combines two levels of observation:

1. **CCI orientation:** the relative organization of the eight perceptual and emotional terrains.
2. **GlycanAge discrepancy:** estimated biological age relative to chronological age.

The discrepancy can be represented as:

GlycanAge − chronological age

A negative value represents an IgG glycan profile estimated as younger than chronological age; a positive value represents a profile estimated as older. The research question is whether particular CCI orientations, factor relations, or terrain invariances correspond to the direction and magnitude of that discrepancy.

Preliminary findings from the ongoing pilot include 27 centenarians assessed with both the CCI and GlycanAge. All produced GlycanAge estimates at least 20 years younger than their chronological ages. Gratitude and Generosity appeared among the four highest-ranked CCI factors in every case. The oldest participants included individuals whose GlycanAge estimates were approximately three decades younger than their chronological ages.

These observations come from a small, selectively surviving population without a matched comparison group. They do not establish that Gratitude or Generosity caused the younger GlycanAge profiles, that the CCI predicts longevity, or that the configuration characterizes all centenarians. They identify a recurrent pattern for replication and controlled testing.

The CCI Time Factor and Durational Projection

The CCI Time factor need not rank highest in someone who expresses an expansive future. This is not contradictory. The Time factor assesses the conscious terrain of experienced duration,

including culturally learned conditions of scarcity, acceleration, and temporal pressure. It does not directly measure Archive Loading, Retrospective Duration Estimate, or Prospective Duration Projection.

Gratitude and Generosity may carry greater durational significance because they constitute meaningful relational experience rather than explicitly evaluate time. Their reciprocal terrain can generate Archive Density and Archive Loading without requiring the individual to conceptualize the experience temporally. The resulting duration may become visible only through retrospective reconstruction or orientation toward future possibility.

The distinction can be stated operationally:

- **CCI Time** identifies the expressed terrain through which duration is consciously experienced and culturally interpreted.
- **Archive Density** identifies the contextual integration among retrievable elements.
- **Archive Loading** identifies the total durationally available archive.
- **Retrospective Duration Estimate** identifies the duration reconstructed from that archive.
- **Prospective Duration Projection** identifies how reconstructed duration informs the availability and pace attributed to the future.

A centenarian can therefore rank relatively low on the CCI Time factor while expressing an expansive Prospective Duration Projection generated through high-load relational terrains. Time is the explicit measure; Graceful Receiving and Graceful Offering may be durational constituents. This distinction is visible in ethnographic interviews. When a 102-year-old participant who was learning German was asked about his progress, he replied that the interviewer should return in three years to see how fluent he would be. The significance is not merely that he remained curious or optimistic. At 102, three future years were experienced as available developmental duration.

The relevant terrain invariance is the absence of culturally imposed durational closure. The future remains sufficiently expansive for learning, training, and increasing competence. IDS proposes that repeated high-load experiences may inform this orientation through retrospective expansion. Durational abundance is then projected forward, organizing the future as a wide and slowly passing field.

A contrasting organization appears when a substantially younger person describes living on borrowed time despite having comparatively greater actuarial time available. Chronological years do not determine either orientation. What differs is the duration constituted as available within the terrain of meaning.

Graceful Receiving ↔ Graceful Offering

The pilot pattern suggests that the reciprocity between Gratitude and Generosity may be more consequential than the rank of either factor alone. This produces a specific IDS hypothesis:

Graceful Receiving ↔ Graceful Offering → increased Archive Density and Archive Loading → retrospective expansion → expansive Prospective Duration Projection

The arrows indicate a heuristic sequence, not an established causal chain. Each relation requires independent measurement.

A non-centenarian pilot case illustrates why the pairing should be investigated longitudinally. At age 54, the participant's CCI profile ranked Health first, Gratitude relatively high, and Generosity sixth. Her initial GlycanAge estimate was 24 years older than her chronological age. Following a nine-month protocol directed toward expanding the Generosity terrain, Generosity moved to second place while the other factor rankings remained unchanged. Her GlycanAge discrepancy decreased from 24 to 19 years older than chronological age.

This single case cannot establish treatment efficacy or causality. Its value is architectural: the only observed CCI ranking change occurred in Generosity while Gratitude was already highly ranked, creating a stronger **Graceful Receiving ↔ Graceful Offering** configuration. The concurrent five-year GlycanAge shift provides a biological change for investigation in controlled longitudinal designs.

The case also demonstrates why Health should not automatically be the factor most closely associated with biological age. CCI Health identifies health as experienced through learned cultural standards. A person may rank Health highly because monitoring, concern, or cultural evaluation strongly organizes the terrain. That ranking does not necessarily indicate biological health or identify the relational conditions through which neuroimmune regulation may occur.

Compensatory Complexity

Centenarians do not escape entropy. They accumulate molecular damage, immune remodeling, cellular senescence, and inflammatory burden. Exceptional longevity therefore cannot be defined as the absence of age-related biological change. Current research instead describes coordinated adaptations through which centenarians preserve immune homeostasis, limit the pathological effects of inflammaging, and maintain disease resistance despite extreme chronological age (Plaza-Florido et al., 2026).

IDS names this organization **Compensatory Complexity**: the coordination of multiple biological and contextual processes in ways that reduce the damage produced by accumulating entropy.

Compensatory Complexity does not reverse entropy and does not require a youthful absence of inflammation. It reduces destructive expression through regulatory diversity, redundancy, flexibility, and coordination. This is compatible with the distinction between inflammaging and

anti-inflammaging, in which longevity reflects the relation between inflammatory burden and counter-regulatory resources rather than the elimination of inflammation (Franceschi et al., 2007). The Th17/Treg findings in centenarians provide a direct immune-level example. Zhou et al. (2022) compared 218 centenarians with 104 older adults and 16 younger adults. Centenarians continued to show elevated levels of several inflammatory markers, confirming that exceptional longevity did not require the absence of inflammaging. However, the Th17/Treg ratio that was elevated in older adults was reduced in centenarians. In ex vivo differentiation assays, centenarian Th17 cells tended to produce fewer proinflammatory cytokines, while their Treg cells showed a greater anti-inflammatory secretory tendency.

The compensation therefore occurred not through removal of inflammatory burden but through reorganization of the ratio and functional expression of immune components. Entropy remained while coordinated regulation reduced its damaging expression. This is the biological architecture identified by Compensatory Complexity.

The correspondence with IDS is structural rather than causal. At the immune level, biological significance emerged from the ratio and functional relation between Th17 and Treg cells rather than from either cell population considered independently. At the CCI level, the working hypothesis similarly concerns the reciprocal organization of Graceful Receiving and Graceful Offering rather than the isolated rank of either factor. The parallel does not establish that the CCI pairing produces the immune ratio. It identifies relational organization as a common level of inquiry across biological and contextual domains.

Terrain invariances may contribute contextual complexity to compensation by organizing relational meaning, threat regulation, social reciprocity, Archive Loading, and future-oriented

engagement. None of these processes alone explains longevity. Their coordination may help preserve biological flexibility in the presence of unavoidable age-related burden.

The resulting heuristic is:

high-load relational terrains → expansive durational projection → sustained future-oriented engagement → increased contextual and biological regulatory complexity

This does not propose that experiencing more duration mechanically produces more chronological years. It proposes that an organism projecting an available future continues to organize learning, relationship, movement, and regulation within that future. There remains more lived duration available for biological unfolding.

The CCI–GlycanAge findings make this architecture testable. Larger samples, matched comparison groups, repeated biological-age measures, direct assessments of Archive Density and Archive Loading, and longitudinal CCI profiles are required to determine whether the centenarian configuration replicates and whether changes in relational terrains precede changes in biological-age markers.

Testable Propositions for IDS Research

IDS becomes scientifically useful when its constructs generate discriminating predictions beyond those available from clock-based models. The following propositions convert the heuristic into a research program with specified tests, competing explanations, and conditions for disconfirmation.

Proposition 1: Experienced Duration Predicts Biological Unfolding

When objective duration is held constant, experimentally altered experienced duration will predict differences in biological or embodied response.

Test: Manipulate temporal cues while assessing experienced duration and measuring glucose regulation, pain, autonomic activity, endocrine response, or immune markers. Because repeated

temporal judgments may alter the experience being measured, duration should be assessed through minimally intrusive concurrent measures, strategically timed probes, or immediate post-interval reports validated against experimental conditions.

IDS prediction: Models incorporating experienced duration will explain biological variation beyond identical clock duration, expectancy, attention, arousal, and other relevant covariates.

Disconfirmation: Temporal manipulation alters experienced duration without corresponding biological change, or the biological variation is fully explained by established mechanisms without additional contribution from experienced duration.

This proposition extends experimental findings involving glucose and pain without assuming that all biological systems respond identically or through the same pathways (Maia et al., 2023; Park et al., 2016; Pomares et al., 2011).

Proposition 2: Archive Loading Predicts Retrospective Duration Estimate

Retrospective Duration Estimate will depend on the durationally available archive generated by an event, not simply on how quickly or slowly the event appeared to pass while occurring.

Test: Present events differing independently in novelty, contextual meaning, and event-boundary frequency. Measure experienced duration during or immediately after the event, then assess Archive Density, Archive Loading, memory accuracy, and Retrospective Duration Estimate.

IDS prediction: Archive Density will contribute to Archive Loading by increasing the integration among retrievable elements. Greater Archive Loading will predict longer retrospective estimates, including for events experienced as passing rapidly while they occurred.

Disconfirmation: Archive Loading does not predict retrospective estimates after objective duration, attention, arousal, event structure, and memory accuracy are controlled.

This proposition distinguishes the experienced rate of an unfolding event from the duration later constructed through its archive (Ma et al., 2024; Morrow et al., 2026; Yue et al., 2026).

Proposition 3: Retrospective Duration Expansion Predicts Prospective Duration Projection

Repeated experiences reconstructed as durationally abundant will predict an expansion in the duration perceived as available to the future.

Test: Measure Archive Density, Archive Loading, and Retrospective Duration Estimate across repeated contextually meaningful experiences. Subsequently assess the available horizon, experienced rate of future passage, perceived distance to future boundaries, and willingness to initiate long-horizon activities.

IDS prediction: Recurrent Retrospective Duration Expansion will predict a more expansive Prospective Duration Projection independently of chronological age, actuarial horizon, mood, optimism, and health status. Expansion of the available horizon need not invariably produce a slower experienced rate; the two dimensions must be tested separately.

Disconfirmation: Prospective Duration Projection is unrelated to prior Archive Loading and reconstructed duration, or the relationship is fully explained by established psychological and demographic variables.

Proposition 4: Graceful Receiving and Graceful Offering Produce a Synergistic Effect

The reciprocal terrain Graceful Receiving ↔ Graceful Offering will generate greater Archive Density, Archive Loading, and prospective durational expansion than either terrain alone.

Test: Compare conditions organized around receiving, offering, reciprocal exchange, and a relationally neutral control. Measure the constituted meaning of each exchange, Archive Density, Archive Loading, Retrospective Duration Estimate, and Prospective Duration Projection.

IDS prediction: The reciprocal condition will produce an interaction effect exceeding the additive contributions of Graceful Receiving and Graceful Offering considered independently.

Disconfirmation: The reciprocal condition produces no interaction effect, or its apparent effects are fully explained by positive affect, social approval, behavioral frequency, or general relational engagement.

This proposition tests the terrain of meaning rather than inferring it from socially recognizable behavior.

Proposition 5: CCI Configurations Correlate With Biological-Age Discrepancy

Variation in biological-age estimates will correspond more closely to configurations among Centenarian Consciousness Index factors than to any single factor considered independently.

Test: Examine CCI factor rankings, Inclusivity Effects, and factor interactions in relation to the discrepancy between GlycanAge and chronological age across centenarian and non-centenarian samples. Analyses should adjust for demographic characteristics, medication, diagnosed illness, health behavior, socioeconomic conditions, and other relevant determinants of glycan aging.

IDS prediction: The reciprocal Gratitude–Generosity configuration will show a stronger association with younger GlycanAge estimates than either factor alone. Explicit Time and Health rankings may show weaker associations if they primarily assess culturally interpreted terrains rather than the relational constituents contributing to Archive Density and Archive Loading.

Disconfirmation: The proposed configurations fail to replicate, provide no predictive value beyond relevant covariates, or show no longitudinal relation to changes in biological-age discrepancy.

GlycanAge should remain one immune-related estimate rather than being treated as a complete representation of biological aging (Krištić et al., 2014).

Proposition 6: Compensatory Complexity Moderates Entropic Damage

Exceptional longevity will correspond not to the absence of inflammaging but to regulatory coordination that limits its damaging expression.

Test: Integrate CCI configurations and durational measures with longitudinal inflammatory, immune, metabolic, functional, and biological-age indicators. Compensatory Complexity should be operationalized through relationships among regulatory processes rather than through the isolated level of any single biomarker.

IDS prediction: Greater Compensatory Complexity will weaken the association between inflammatory burden and functional deterioration. Individuals with comparable inflammatory burden may exhibit different biological consequences according to the organization of their regulatory relations.

Disconfirmation: Measures of regulatory complexity do not moderate the relationship between inflammatory burden and biological decline, fail to predict functional preservation, or add no explanatory value beyond established biological variables.

This proposition is consistent with evidence that centenarians can retain inflammatory burden while exhibiting regulatory adaptations associated with preserved function. The reduced Th17/Treg ratio and differentiated cytokine expression observed in centenarians provide a specific immune-level example of such compensatory organization, without establishing that IDS terrains cause that organization (Franceschi et al., 2007; Plaza-Florido et al., 2026; Zhou et al., 2022).

Together, these propositions establish a progressive evidentiary standard:

association → temporal precedence → experimental manipulation → biological convergence → cross-cultural replication

IDS would gain support only if its constructs demonstrate reliable measurement and explain additional variance beyond objective time, memory performance, affect, expectancy, health behavior, and established biological predictors. Its scientific value does not lie in redescribing known findings in durational language. It lies in identifying relations that existing models do not measure, specifying how those relations can be tested, and defining the evidence that would support, modify, or require rejection of the heuristic.

Conclusion: Duration as an Organizer Rather Than a Measure

ime allows change to be measured. It does not, by itself, explain how change is experienced, archived, projected, or biologically expressed. The Internal Duration Setting heuristic introduces experienced duration as an organizing condition within which biological processes unfold.

This proposal does not replace clock time, established physiology, or molecular mechanisms. It identifies a level of organization that conventional measurements can overlook. When objective duration or material input remains constant but glucose regulation, pain, or response onset changes with the durational condition, clock measurement is insufficient to explain the difference. IDS asks what was constituted within the measured interval that became consequential to the organism.

Experienced duration is neither a unitary sensation nor another name for perceived time. Its organization includes how duration passes during an event, how contextual meaning shapes Archive Density and Archive Loading, how the resulting archive informs Retrospective Duration Estimate, and how reconstructed duration may be projected toward the future. These functions can diverge. An experience may pass quickly while occurring yet become durationally expansive in retrospect because it generated a highly differentiated and contextually integrated archive. Recurrent retrospective expansion may then contribute to a future experienced as abundantly available rather than rapidly closing.

This architecture gives relational meaning an operational role. Graceful Receiving and Graceful Offering are proposed as reciprocal terrains capable of generating high Archive Density and Archive Loading because they integrate value, embodiment, emotional salience, self–other relevance, and the possibility of future reciprocity. Their potential biological relevance does not depend on a generalized claim that positive emotions improve health. It lies in how relational terrains may jointly organize duration, threat regulation, neuroimmune activity, and continued engagement with future possibility.

The CCI makes aspects of this inquiry measurable. Derived from ethnographic content analysis of healthy centenarians across cultures, it identifies perceptual and emotional terrain invariance factors rather than reducing centenarian functioning to personality traits or visible behaviors. Examining CCI configurations in relation to GlycanAge introduces an independent immune-related estimate of biological age. Preliminary observations do not establish causality, but they identify a coherent pattern: substantially younger GlycanAge estimates occurring alongside consistently elevated Gratitude and Generosity orientations.

This pattern clarifies why the explicit CCI Time factor need not be the primary carrier of durational expansion. The Time factor assesses the consciously interpreted terrain of temporal experience. Relational factors may participate in constituting the meaningful experiences through which duration acquires Archive Density, becomes retrospectively expansive, and is projected forward. The centenarian orientation of having “all the time in the world” may therefore emerge less from thinking about time than from repeatedly inhabiting experiences rich enough to sustain an expansive future.

Compensatory Complexity places this proposition within biological reality. Centenarians do not violate entropy or avoid every feature of inflammaging. Their distinction may lie in coordinated

processes that reduce the damage associated with accumulated biological burden. The preservation of regulatory relationships despite persistent inflammatory activity provides a biological form of compensation without exemption from aging. IDS proposes that durational and relational terrains may participate in this organization without claiming that they operate independently of genetics, metabolism, immune regulation, environment, or behavior.

The scientific value of IDS will depend on whether its constructs provide explanatory and predictive power beyond established variables. Experienced Duration, Archive Density, Archive Loading, Retrospective Duration Estimate, Prospective Duration Projection, Temporal Boundary Expectation, relational synergy, and Compensatory Complexity must be operationalized distinctly, tested against competing explanations, and examined across biological systems and cultures. Findings that fail to distinguish these constructs from attention, memory, affect, expectancy, or objective duration would require modification or rejection of the heuristic.

The proposition is therefore deliberately constrained: experienced duration may organize biological unfolding, but the pathways, boundaries, and magnitude of that influence remain empirical questions. Glucose, pain, neuroimmune regulation, and biological aging are supporting domains through which the proposition can be tested; none is the singular theme of the inquiry.

The broader shift is epistemological. When elapsed time is used as the explanation for biological change, the measure assumes the role of the constituent presumed to produce what it records. Restoring time to its function as measure makes the organization of the measured interval available for investigation. IDS provides a vocabulary and research architecture for examining that organization.

Biology does not merely change as time passes. It unfolds within the duration an organism constitutes, retains, and projects as possible.

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