

Memento Mori: A Minimal Computational Framework for Subjective Temporal Experience

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Abstract

Time is not only measured but lived: equal calendar durations can feel compressed or expanded depending on routine, anticipation, and salient events. We introduce a minimal, theory-neutral computational framework that represents subjective time as a monotonic transformation of calendar time via an interpretable weighting of days. The framework is instantiated in an interactive visualization, *Memento Mori*, which makes subjective temporal assumptions explicit and manipulable, providing a formal scaffold for reasoning about lived time in cognitive science and human-centered AI.

Keywords: subjective time, time perception, cognitive modeling, human-computer interaction, visualization

1 Introduction

Human experience unfolds in time, yet the time that structures experience is not identical to the time recorded by clocks and calendars. Days filled with routine may appear to pass quickly, while periods marked by novelty, uncertainty, or anticipation often feel extended. Such distortions are not anomalies; they are systematic features of cognition that shape memory, decision-making, motivation, and subjective well-being (Block and Zakay, 1997; Wittmann, 2013). Calendar time provides a uniform metric, but lived time is structured, uneven, and context-sensitive.

Across psychology, phenomenology, and cognitive science, subjective time has been studied through duration judgments, memory-based reconstructions, and qualitative descriptions of lived temporality. Despite this breadth, subjective temporal experience is rarely treated as a manipulable computational object. Assumptions about lived time typically remain implicit, making them difficult to compare, formalize, or integrate into interactive systems and human-centered artificial intelligence.

This paper proposes a minimal computational framework for subjective temporal experience. The core idea is to represent lived time as a structured transformation of calendar time, parameterized in an interpretable and theory-neutral way. Rather than committing to a specific psychological account, the framework provides a small space of assumptions that can be made explicit, compared, and revised.

We instantiate this framework in an interactive visualization system, *Memento Mori*, which renders subjective time as a manipulable structure rather than a fixed timeline. Users can move a temporal anchor, switch between objective and subjective remaining time, and adjust parameters that jointly control both numerical outcomes and perceptual structure.

The contribution is methodological rather than empirical: a minimal formal representation and interactive instrument for reasoning about subjective temporal structure.

Figure 1 provides an overview of the *Memento Mori* interface, illustrating how calendar time, subjective remaining time, and parametric assumptions are brought into a single interactive representation. The interface is designed to externalize assumptions about lived temporal structure rather than to optimize prediction or efficiency.

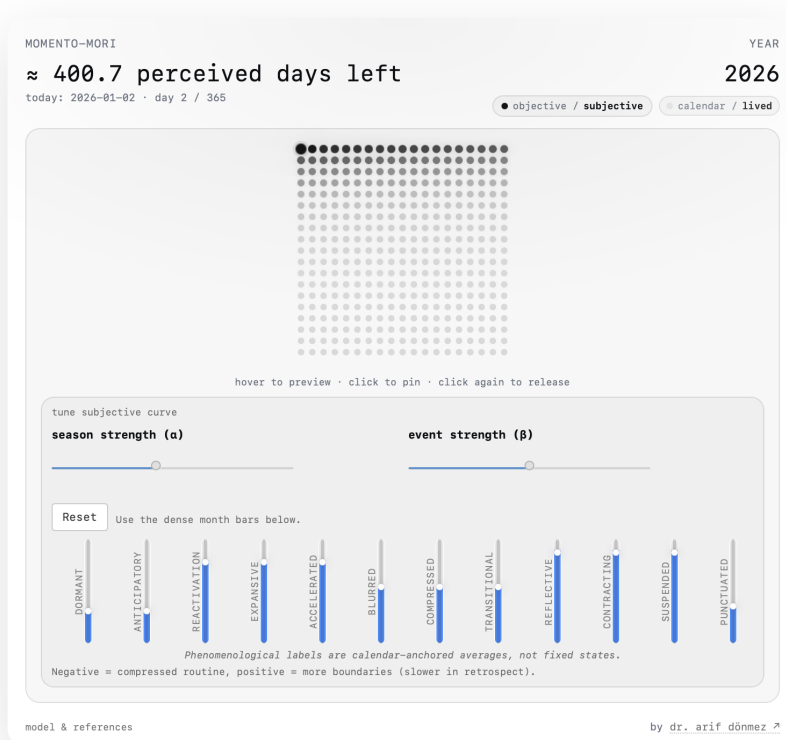


Figure 1: Overview of *Memento Mori*. Calendar time is represented as a grid of days. A movable temporal anchor defines the experienced present. Subjective remaining time and perceptual warping update as assumptions about temporal structure are adjusted.

2 Background and Related Work

The experience of time has been examined across philosophy, psychology, and cognitive science. While clock time provides a uniform and objective metric, lived time is irregular, context-dependent, and structured by perception, memory, and anticipation. Across disciplines, researchers have repeatedly emphasized that temporal experience cannot be reduced to the measurement of duration alone.

In phenomenological philosophy, time is treated not as an external parameter but as a fundamental structure of experience. Classical accounts describe temporality as an integrated field in which retention of the immediate past, impression of the present, and protention toward the future coexist (Husserl, 2012). Later phenomenological and existential perspectives further emphasize how meaning, affect, and life context shape temporal experience (Merleau-Ponty et al., 2013). These traditions provide rich descriptive insight into lived time, but they generally resist formalization and offer limited guidance for computational representation.

Psychological and cognitive research approaches subjective time from a different angle, focusing on duration estimation, temporal reproduction, and memory-based judgments. Empirical findings consistently show that perceived duration depends strongly on attention, arousal, novelty, and event density, particularly in retrospective assessments (Block and Zakay, 2008; Eagleman, 2008). These models demonstrate that subjective time is systematically distorted rather than noisy, yet they are typically tied to specific experimental paradigms and short time scales. As a result, they offer limited tools for reasoning about extended temporal experience across weeks, months, or years.

In computational systems and human–computer interaction, time is most often treated as a uniform index or coordinate. While alternative visual representations—such as radial calendars or event-based timelines—have been explored, these approaches tend to remain descriptive rather than model-driven. Interactive systems that allow users to explicitly manipulate assumptions about subjective temporal structure, or to compare calendar time with experienced time, remain rare.

Taken together, these strands reveal a persistent gap. Phenomenological accounts offer conceptual depth without formal structure; psychological models provide quantitative insight but remain locally scoped; computational representations prioritize uniformity at the expense of lived structure. The present work addresses this gap by introducing a minimal computational framework that makes subjective temporal assumptions explicit, interpretable, and interactively explorable, without committing to a single explanatory theory.

3 A Minimal Computational Framework for Subjective Time

The central assumption of this work is that subjective temporal experience can be modeled as a structured transformation of calendar time rather than as an independent temporal dimension. Calendar time provides an ordered sequence of discrete units, while subjective time reflects how experiential distance accumulates unevenly across those units.

3.1 Temporal Domain and Weighting

We consider a finite interval consisting of N ordered calendar days,

$$t \in \{1, \dots, N\}.$$

Objective time corresponds to the identity mapping in which each day contributes equally. Subjective time is modeled by assigning each day a strictly positive weight

$$w(t) > 0,$$

interpreted as its relative experiential contribution. Days experienced as salient or dense contribute more strongly than days experienced as routine or compressed.

3.2 Cumulative Subjective Time

Subjective time is defined as the cumulative sum

$$S(t) = \sum_{\tau=1}^t w(\tau),$$

which induces a monotonic but generally non-linear transformation of calendar time. Temporal order is preserved, but equal calendar intervals may correspond to unequal subjective distances.

3.3 Parametric Structure

To maintain interpretability, the weighting function is constructed from a small number of components:

$$w(t) = 1 + \alpha f_{\text{season}}(t) + \beta f_{\text{event}}(t),$$

where $f_{\text{season}}(t)$ captures slow contextual rhythms and $f_{\text{event}}(t)$ captures localized deviations. Parameters α and β control their respective influence and are zero-centered to preserve global scale.

3.4 Temporal Anchors and Remaining Time

Subjective temporal distance is evaluated relative to an anchor day t_0 , treated as the experienced present. Objective remaining time is

$$T_{\text{obj}} = N - t_0,$$

while subjective remaining time is

$$T_{\text{subj}} = S(N) - S(t_0).$$

This distinction between calendar and experiential futures is illustrated in Figure 2, which contrasts objective and subjective remaining time for the same temporal anchor. The figure makes explicit that subjective temporal distance can diverge substantially from calendar distance without altering temporal order.

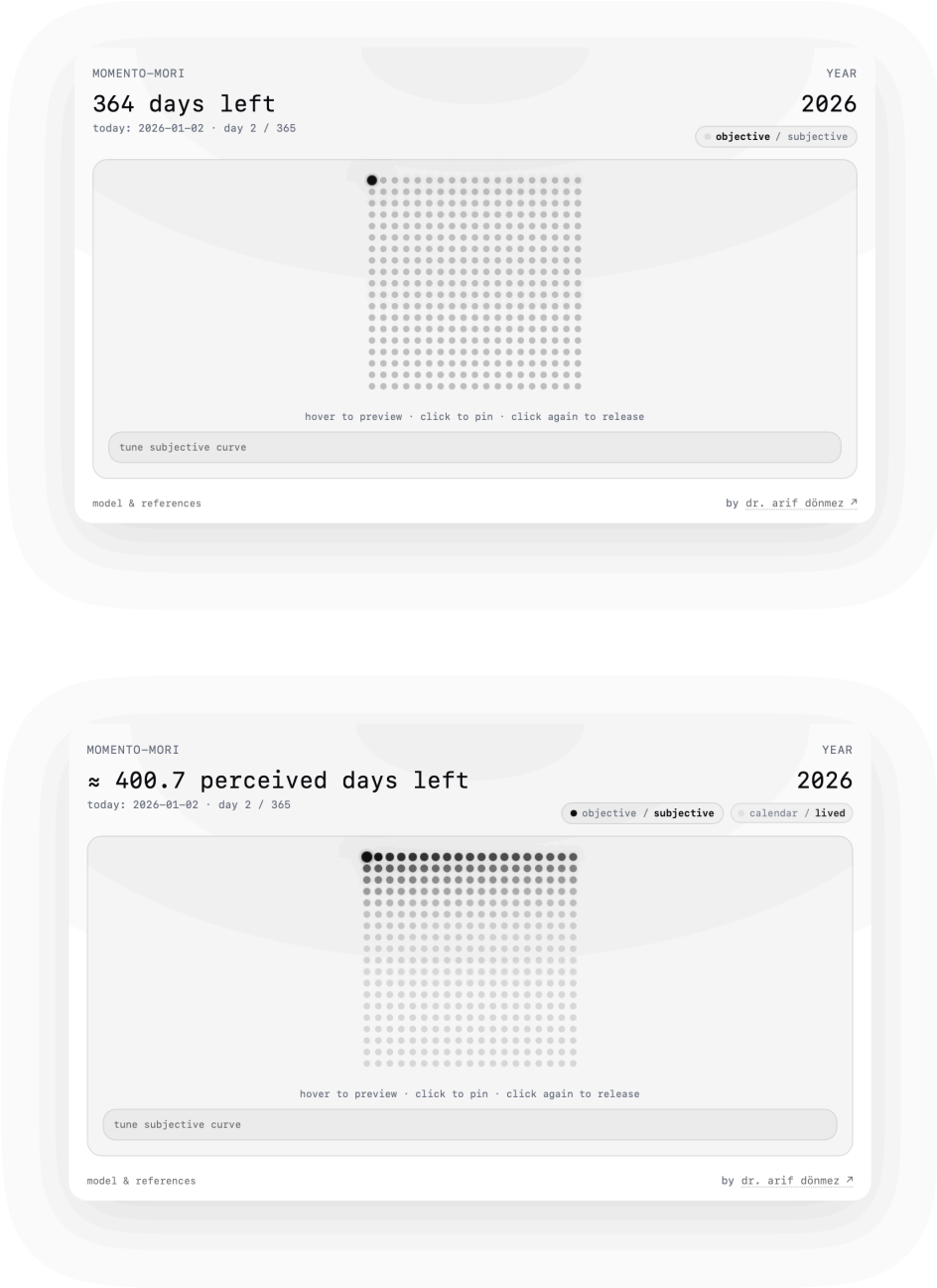


Figure 2: Objective versus subjective remaining time for the same anchor position. Equal calendar futures may correspond to different subjective distances depending on the assumed weighting.

This formulation captures the intuition that the future may feel closer or farther without altering calendar structure.

4 Visualization and Interaction Design

The framework is instantiated in an interactive visualization, *Memento Mori*, designed to make subjective temporal assumptions perceptually accessible. The visualization functions as an epistemic interface rather than a conventional data display.

Calendar time is represented as a grid of discrete elements, each corresponding to a day. This representation emphasizes accumulation rather than flow and discourages assumptions of uniform progression.

Interaction is structured around a temporal anchor. Hovering over a day previews remaining time, while pinning stabilizes the anchor. Switching between objective and subjective modes makes the divergence between calendar time and lived time explicit.

Figure 3 and Figure 4 illustrate how different assumptions about temporal structure shape both numerical estimates of remaining time and the perceptual organization of the temporal field. While the underlying calendar structure remains fixed, subjective expansion emerges through changes in weighting and accumulation.

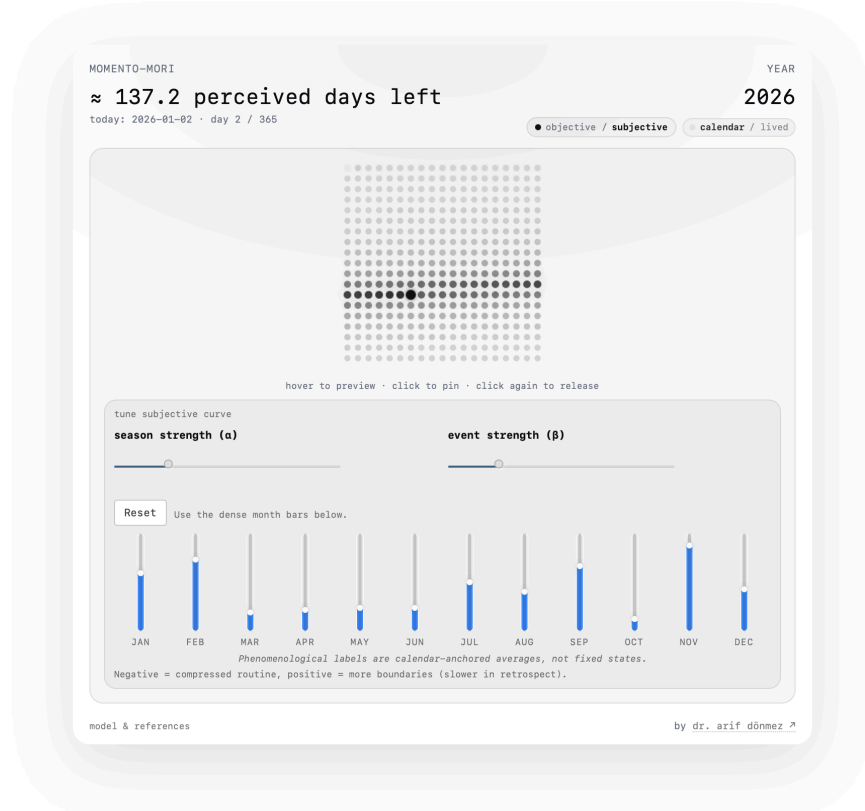


Figure 3: Low subjective expansion. Weak seasonal and event modulation yields a compressed subjective future, reflected in both reduced perceived remaining time and minimal visual warping around the temporal anchor.

In the low-expansion regime shown in Figure 3, subjective time closely tracks calendar time, resulting in a compressed experiential future and minimal visual distortion. In contrast, Figure 4 demonstrates how stronger seasonal and event modulation produces an expanded subjective future, accompanied by pronounced perceptual warping around the temporal anchor.

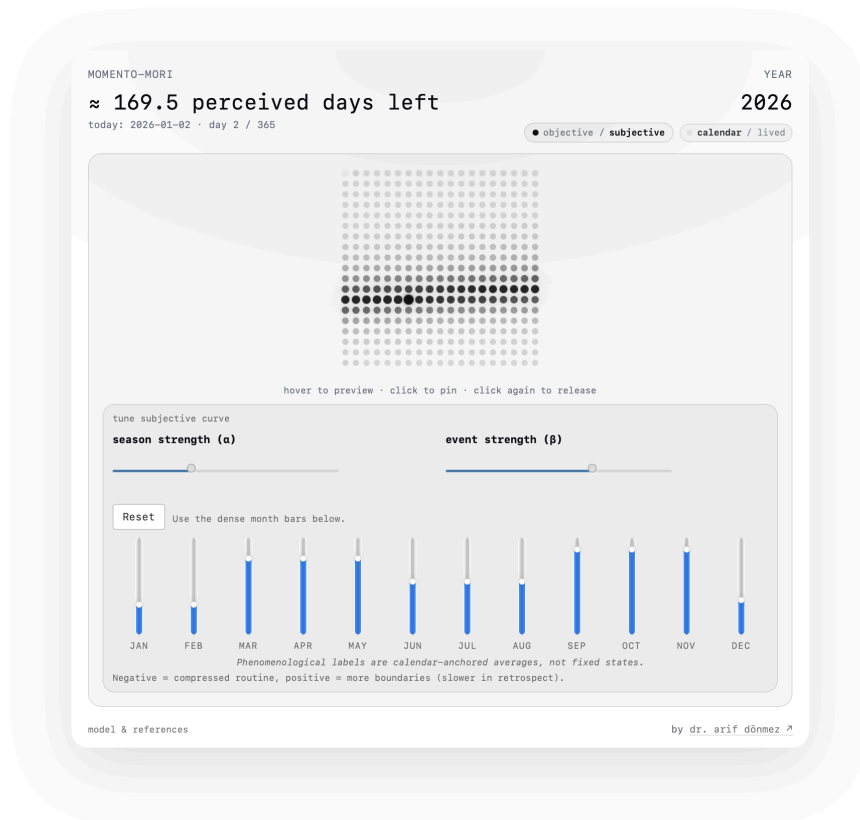


Figure 4: High subjective expansion. Stronger seasonal and event modulation increases subjective remaining time and produces pronounced perceptual warping, indicating an expanded experiential future.

Importantly, parameter changes affect both numerical output and visual structure. This coupling ensures that assumptions about subjective time remain cognitively legible rather than abstract.

The interactive system described in this section is publicly available as a web-based application.¹ The deployment is intended as a research artifact that allows readers to directly explore the framework’s assumptions and their perceptual consequences.

¹A live version of *Memento Mori* is available at <https://arifdoenmez.shinyapps.io/memento-mori/>.

5 Illustrative Scenarios

These scenarios are not empirical demonstrations but conceptual probes that illustrate how subjective temporal structure emerges from interaction with the framework.

5.1 Traversing the Year

Moving the temporal anchor across the calendar produces linear changes in objective remaining time but non-linear changes in subjective remaining time. This reflects a common cognitive operation: imaginatively placing oneself at different points in time to assess the future.

5.2 Comparing Futures

Anchoring the present at different points with equal calendar futures reveals differences in subjective distance. Futures dominated by routine may feel closer than equally long futures containing anticipated transitions or dense activity.

5.3 Adjusting Assumptions

Modifying parameters while holding the anchor fixed reshapes both the cumulative mapping and the visual warp. This treats parameters as explicit hypotheses about lived temporal structure rather than hidden model internals.

6 Discussion

The proposed framework captures a central feature of temporal experience: equal calendar durations need not feel equal. By modeling subjective time as a monotonic but non-uniform transformation, the framework accommodates temporal compression and expansion without violating temporal order.

A deliberate design choice is interpretability over psychological realism. Rather than competing with mechanistic models of interval timing (Wittmann, 2013), the present framework targets extended, structurally experienced time. The model abstracts away from neural mechanisms and short-interval timing in favor of conceptual clarity. This trade-off enables explicit reasoning about subjective temporal assumptions but limits predictive scope.

The visualization plays a critical epistemic role. By coupling numerical outcomes to perceptual structure, it externalizes subjective assumptions in a form that can be inspected and compared. Subjective time is neither reduced to narrative nor obscured by opaque computation.

The framework is not intended to predict duration judgments, but to externalize and compare assumptions about extended temporal experience.

The contrast between Figures 3 and 4 highlights that subjective time is not merely rescaled calendar time but a structurally reorganized temporal field, reinforcing the need for representations that integrate computation and perception.

The framework is descriptive rather than normative. Its value lies not in prediction, but in making lived temporal structure formally representable and interactively explorable.

7 Implications and Future Work

The framework suggests several extensions that preserve its minimal and interpretable character. Empirically, parameters could be calibrated using retrospective duration judgments or longitudinal self-reports, focusing on extended temporal experience rather than momentary timing.

Longitudinal personal models could support reflection on how temporal experience changes across life phases or routines. In clinical or well-being contexts, the framework may function as a communicative aid rather than a diagnostic instrument.

Alternative temporal units—such as weeks, projects, or life events—could replace calendar days without altering the core structure. From an HCI perspective, the work highlights ethical considerations: while individualized subjective-time models could be used to shape engagement, transparency and user agency must remain central.

More broadly, the framework points toward a class of research instruments that formalize subjective experience without collapsing it into a single theory.

8 Conclusion

Subjective time is not merely measured but lived. This work introduced a minimal computational framework that represents lived temporal experience as an interpretable transformation of calendar time. By combining formal simplicity with interactive visualization, the framework makes subjective temporal assumptions explicit and manipulable.

Rather than proposing a new theory of time perception, the contribution lies in representation and method. *Memento Mori* demonstrates how phenomenological insight, cognitive modeling, and interaction design can be combined to make lived time computationally tractable without reducing its complexity.

Minimal, interpretable models of subjective experience—paired with carefully designed interaction—offer a promising path for cognitive science and human-centered AI.

The accompanying interactive implementation allows the framework to be inspected, manipulated, and extended beyond static presentation, supporting its use as a research instrument rather than a fixed model.

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