We want to model cultural "memory" decay in the context of a trait not being practiced for a certain amount of time. This will be the functioning of a trait inside a node in a cultural network.

The assumption is that, as long as the trait is performed, it does not decay.

Then, once the trait is not performed (be it for lack of resources, dependence on other cultural traits, out of fashion, etc.)

The trait starts to decay in a given way. Our initial assumption is a log-normal way depending on a decay rate ∂ and an initial knowledge k_0

Then, once the trait is performed again (be it because the resources are back, the fashion comes back, the dependence is fulfilled...) its knowledge/memory is replenished to initial values.

This model has the following parameters:

- k_0 initial knowledge $= 1$
- t_s time step $= 0.1$
- g_t generation time $= 300 \cdot t_s$
- N number of runs $= 333$
- L sequence length $= 1000$

and the following variables:

- ∂ decay rate
- f frequency of performance
- ϵ_f error or noise in the frequency of performance
- ϵ_k knowledge or memory error in performance

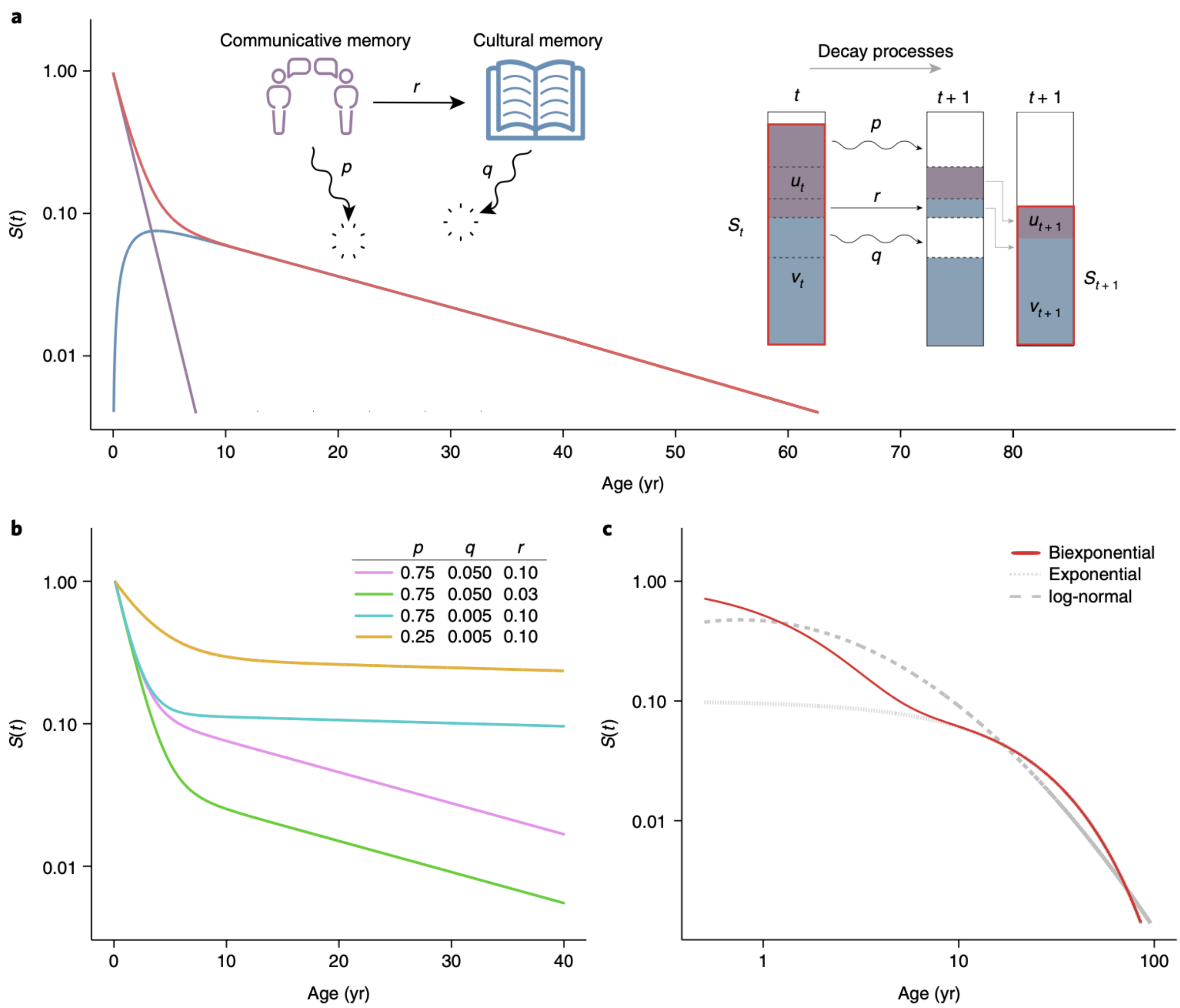
Cultural decay function

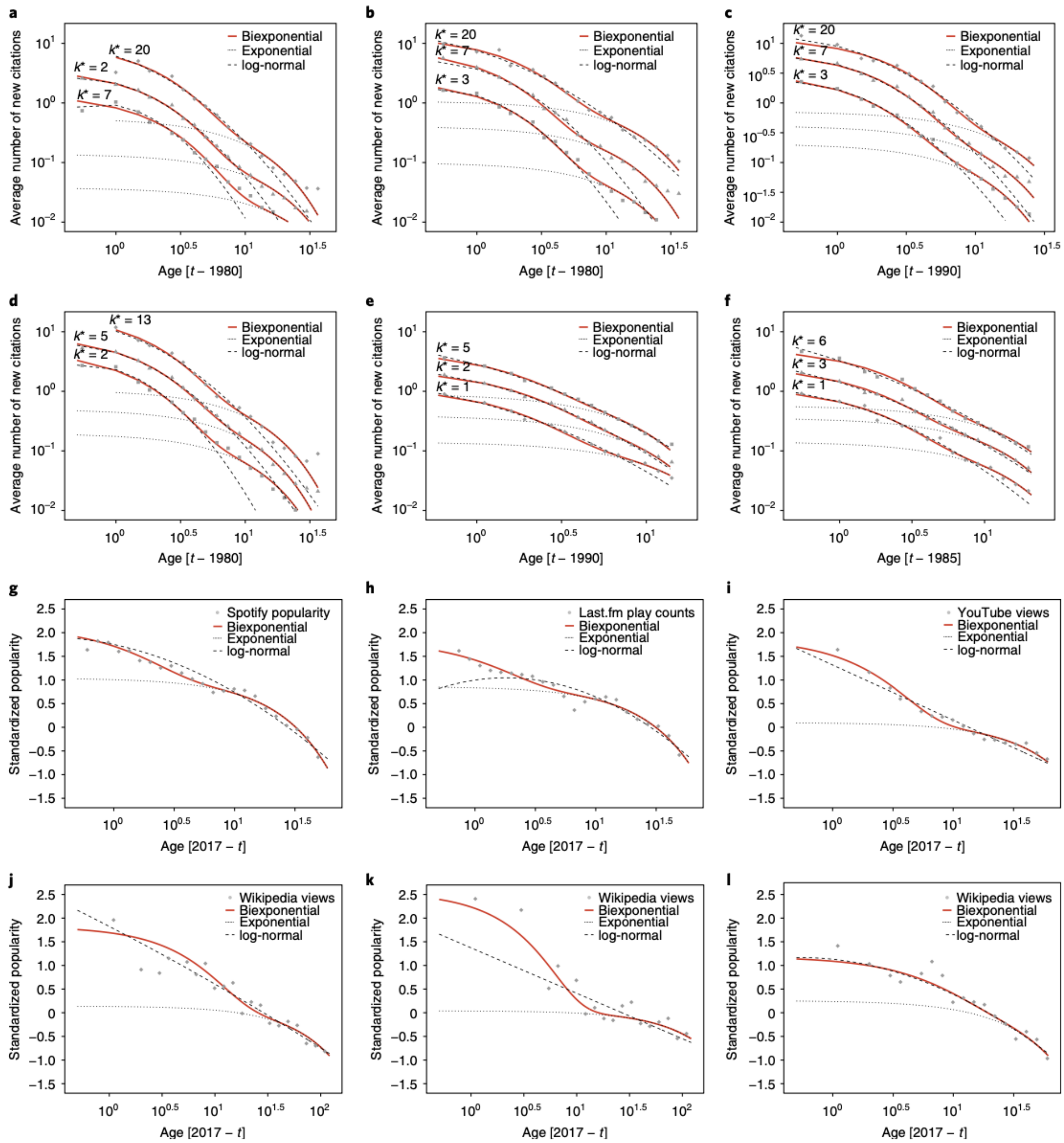
inspired from:

- Halbwachs, M. On Collective Memory (Univ. Chicago Press, Chicago, 1992)
- Assmann, J. in Cultural Memory Studies. An International and Interdisciplinary Handbook (eds Erll, A. & Nünning, A.) 109–118 (Walter de

Gruyter, Berlin, 2008).

- https://doi.org/10.1038/s41562-018-0474-5 The universal decay of collective memory and attention, Canadia 2019





The cultural memory only part on their model (neglecting the communicative memory) can be summarised as a log-norm decay

$$\frac{dk}{dt} = -k \cdot \partial,$$
$$k(t) = k_0 e^{-t\partial} = e^{c-t\partial},$$
$$c = \log(k_0).$$

where, d on the left side, first expression, is the derivative of knowledge over time. ∂ is the decay rate, k_0 accounts for the initial knowledge in our rendering of the model.

Embers (or quest for fire) model: trait decay and recovery

If $k(t) < \epsilon_k \ \ \rightarrow k(t) = 0$, where ϵ_k is a knowledge threshold beyond which, if the knowledge is not enough, the trait is considered to be lost. *For the Olympiads is a complex one, as it was alive in living memory, even though the event was not performed for thousands of years, but it needed other prerequisites before recreating the games, like Greek independence and the revival of athletics.* Thus, in theory, ϵ_k can be arbitrarily low.

$$k(t) = \begin{cases} e^{c-\partial\Delta t} + [k_0 - k(t-t_s)] \cdot R(t) \ \text{ if } \ k(t-t_s) > \epsilon_k \\ 0 \ \text{ if } \ k(t-t_s) < \epsilon_k, \end{cases}$$

where $R(t)$ is the recurrence of the cultural trait,

\begin{equation} R(t) = (t+n(t)) \% f \end{equation}

R(t) = [t+n(t)] \, \text{mod} \, f

thus, $R(t)$ can have the values

$$R(t) = \begin{cases} 1 \\ 0 \end{cases}$$

and $\epsilon_f(t)$ is a noise value normally distributed around $\mu = 0$ with variance $\sigma = t_s \ \epsilon_f(t) = N(0, t_s^2) \ \exists \ [-\infty, \infty]$.

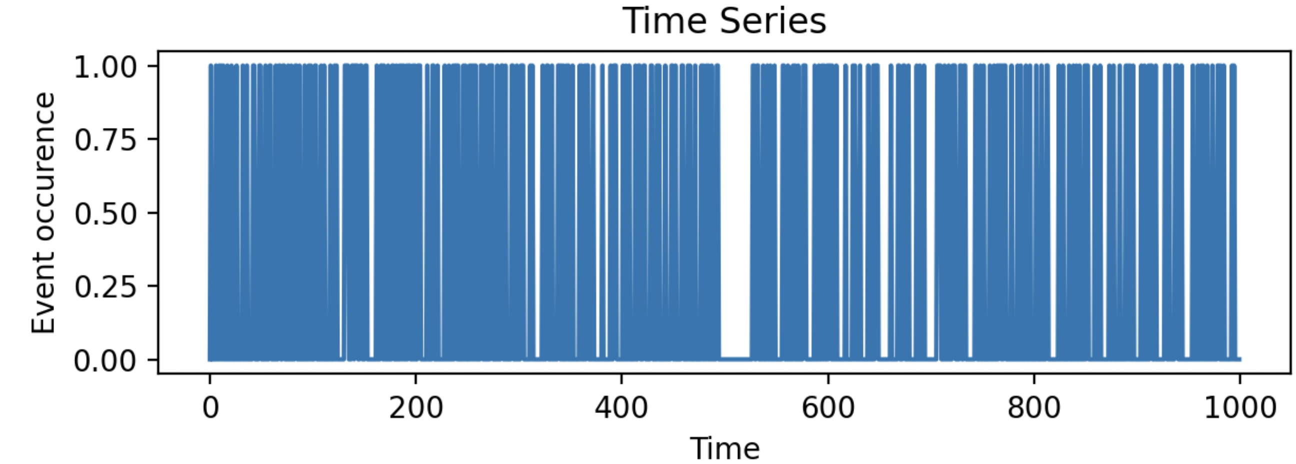
R(t) = [t+n(t)] \% f
$R(t) = [t + n(t)] \, f$

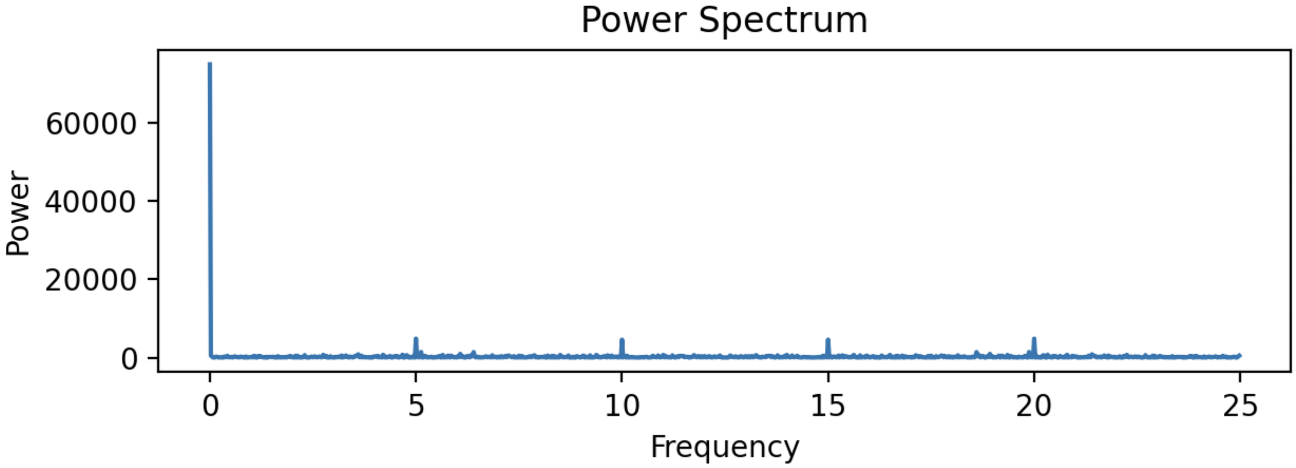
Δt is the time interval since the last time $R(t) = 1$, i.e. how many time steps t_s ago the last expression event happened. For example, the Olympiads happen every 4 years, thus $\Delta t = f = 4$, but in Covid year they were delayed one year, so $\Delta t = 5$. In the case of WWI $\Delta t = 8$ and for WWII $\Delta t = 12$.

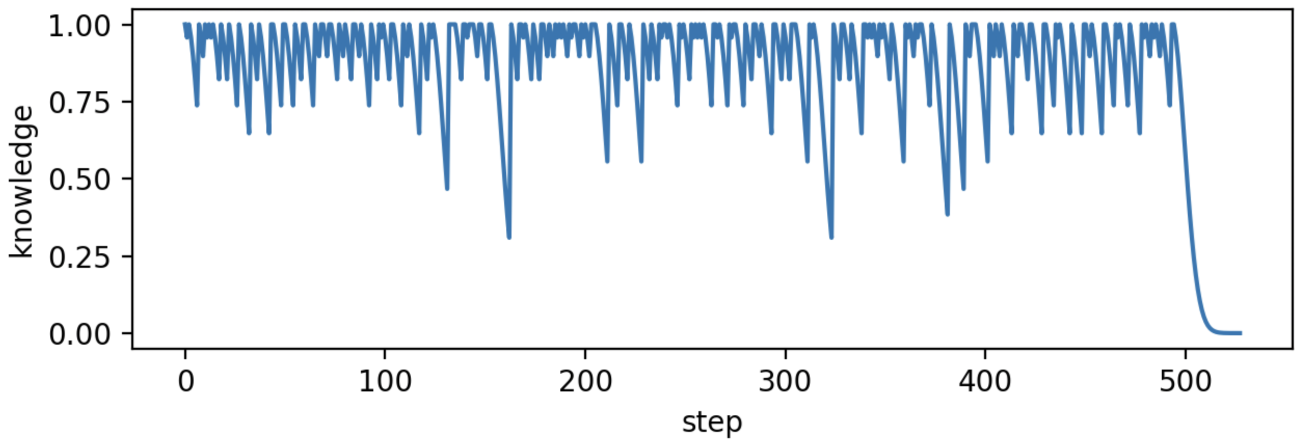
For practical proposes, I'm considering that the threshold is one order of magnitude lower than the initial condition, or $\epsilon_k = 1/10$.

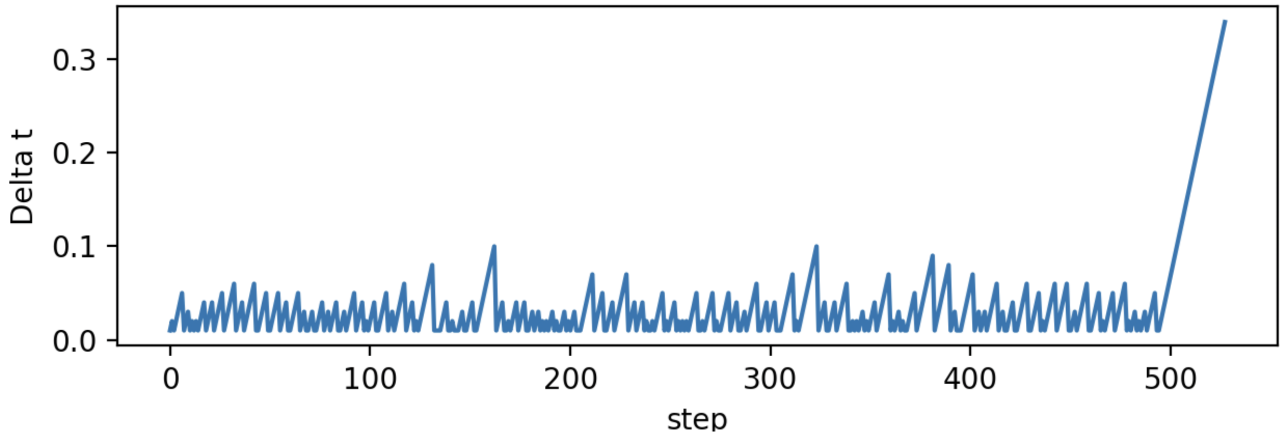
Then, for a continously recurring event: $R(t) = 1 \rightarrow$
$\Delta t_{max} = f_{th} = -\log(\epsilon_k / k_0)/\partial = -[\log(\epsilon_k) - c]/\partial$,
$f_{th}(\epsilon_k = 0.1 \cdot k_0) = -2.3/\partial$

One realization for $f = 5, t_s = 0.01, \partial = 2.3/f, n = 0.66$

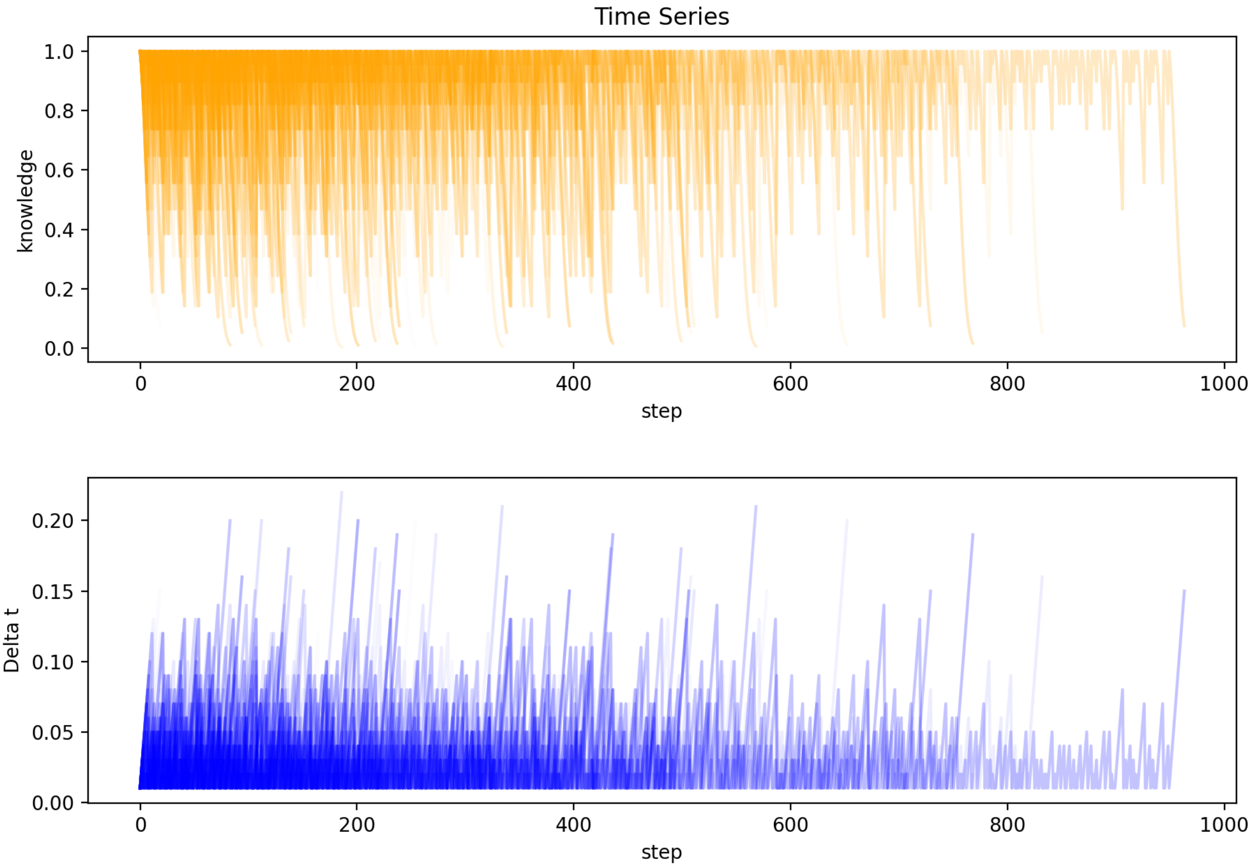




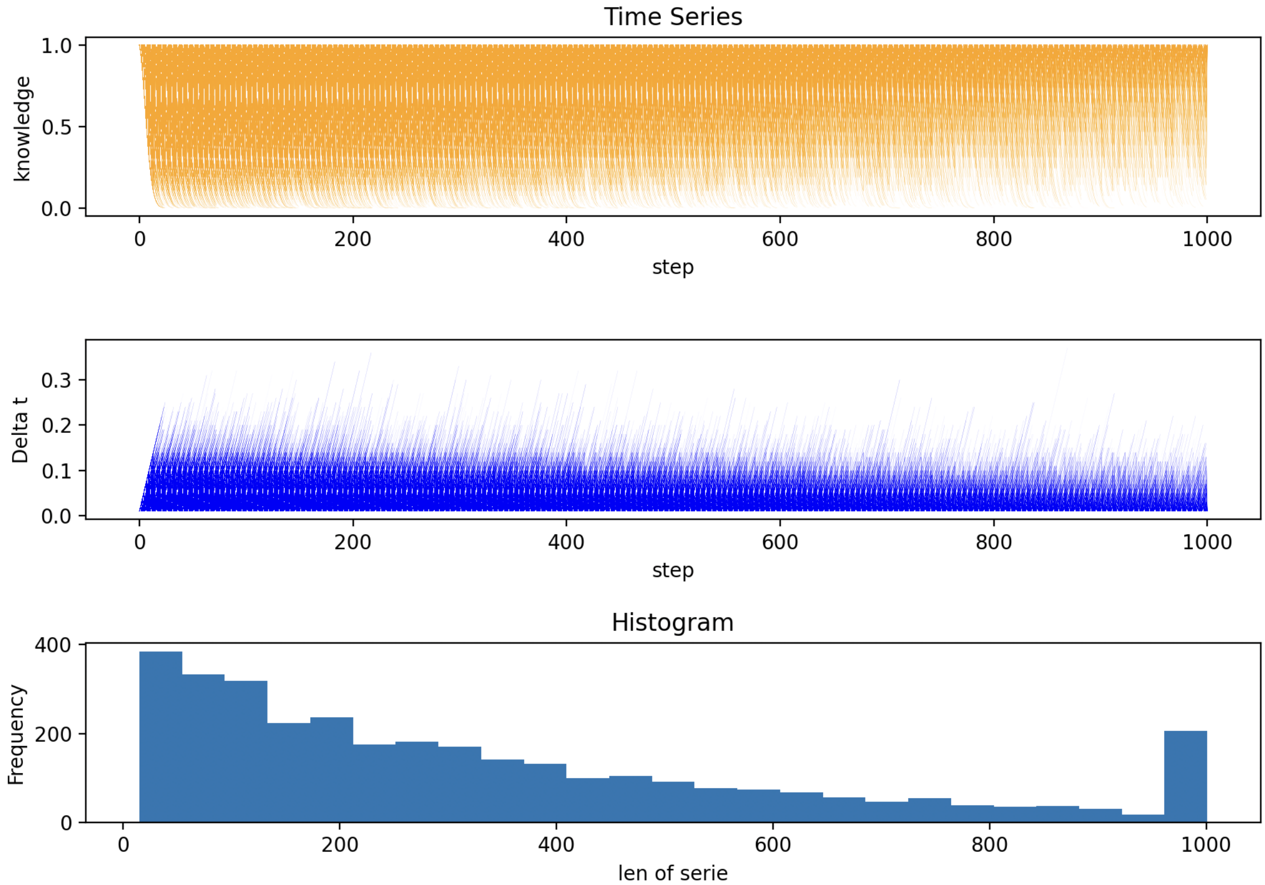




For 33 realizations



For 3333 realizations



After-loss Innovation model

This model expands on the embers model with the assumption that a cultural trait can be reinvented and culturally acquired after it has disappeared from the cultural memory.

It assumes that there is an Innovation rate $I(t)$ where there is a non-zero chance of recreating the initial cultural trait that was lost from cultural memory but can be found in the archaeological record. An example is the discontinuity of the use of concrete for about 1500 years in Western Europe [HISTORY OF CONCRETE FROM ROMAN TIMES TO THE EIGHTEENTH CENTURY, JANET IRENE ATKINSON, 1979]. Though, in this case, the occurrence of natural events where the resources might be available can be considered continuous, what is broken is the trade network to link resources and knowledge.

This model has the following additional parameters:

- A_{th} acquisition threshold
- a acquisition rate of a lost trait
- σ variance on acquisition

The model can be descrived by:

$$k(t) = \begin{cases} e^{c-\partial\Delta t} + [k_0 - k(t-t_s)] \cdot R(t) \text{ if } k(t-t_s) & nbsp; > \epsilon_k \\ I(t) \text{ if } k(t-t_s) & nbsp; < \epsilon_k \end{cases}$$

where $I(t) = k_0 \cdot R(t) \cdot A(t)$

$$A(t) = \begin{cases} 1 \text{ if } N(a, \sigma) & nbsp; > A_{th} \\ 0 \text{ if } N(a, \sigma) & nbsp; < A_{th} \end{cases}$$

$A(t)$ is the acceptation or not of a newly innovated previously lost cultural trait.
Thus, given the conditions are right, i.e. $R(t) = 0$
It would be accepted with a probability depending on whether the normal distribution $N(a,\ \sigma)$ is bigger or smaller than a set threshold of acquisition A_{th}.
a is the mean acquisition rate
σ is the variance on the acquisition

Neurological memory decay

https://www.sciencedirect.com/science/article/pii/S0749596X14000084

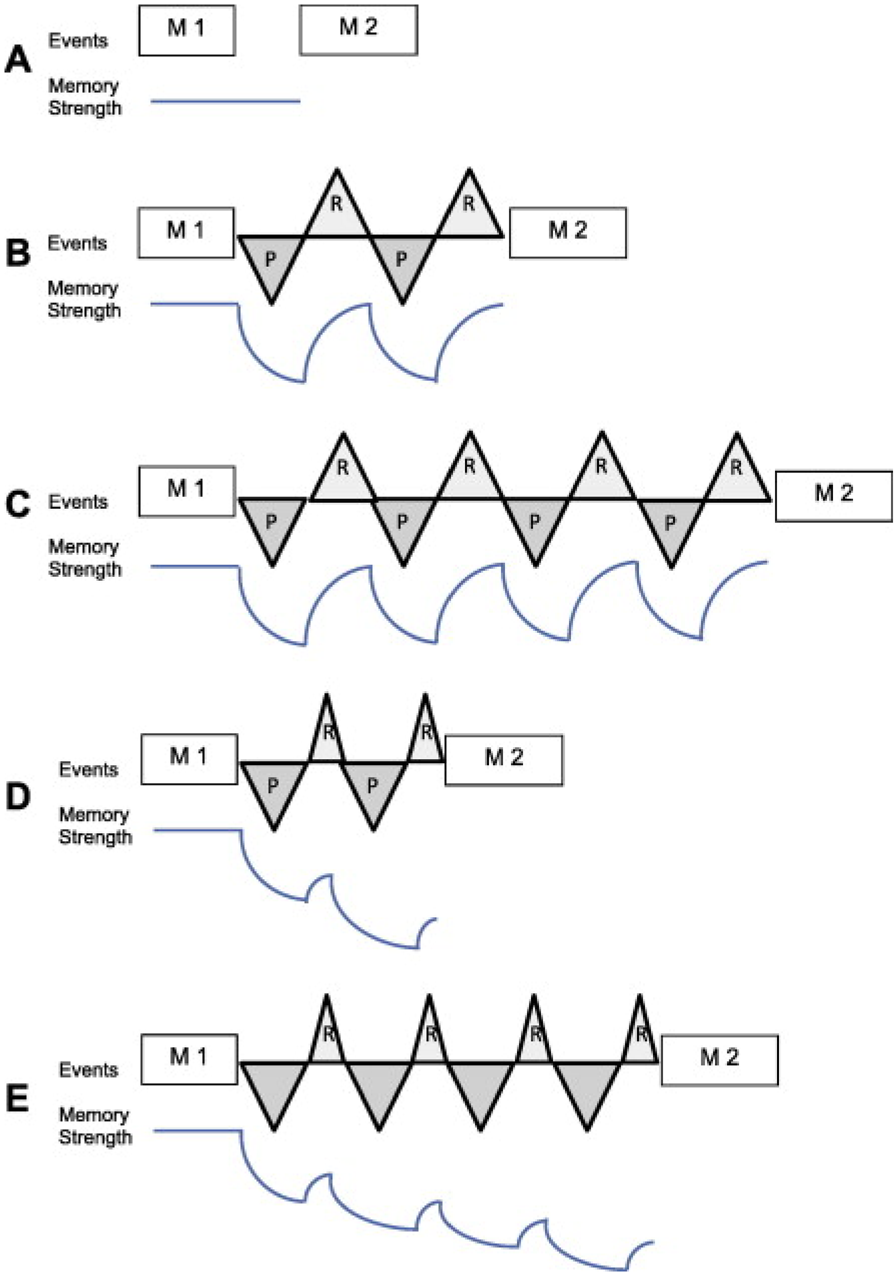


Fig. 1. The interplay of decay and refreshing in the time-based resource-sharing (TBRS) theory. (A): Simple span (no distractor processing): Memory strength of item M1 remains undiminished at least until encoding of the following item M2. (B and C): Complex span at very low CL: Decay during distractor processing (triangles marked P) is fully offset by refreshing during free time (triangles marked R). Memory strength of M1 remains undiminished until encoding of M2, as in simple span. As a consequence, predicted memory performance is equal for zero distractors (A), two distractors (B), and four distractors (C). (D and E): Complex span at higher CL, such that refreshing only partially offsets decay. Memory strength declines with every processingrefreshing cycle, and therefore declines more with four operations (E) than with two operations (D)

https://doi.org/10.1007/s00426-002-0102-9

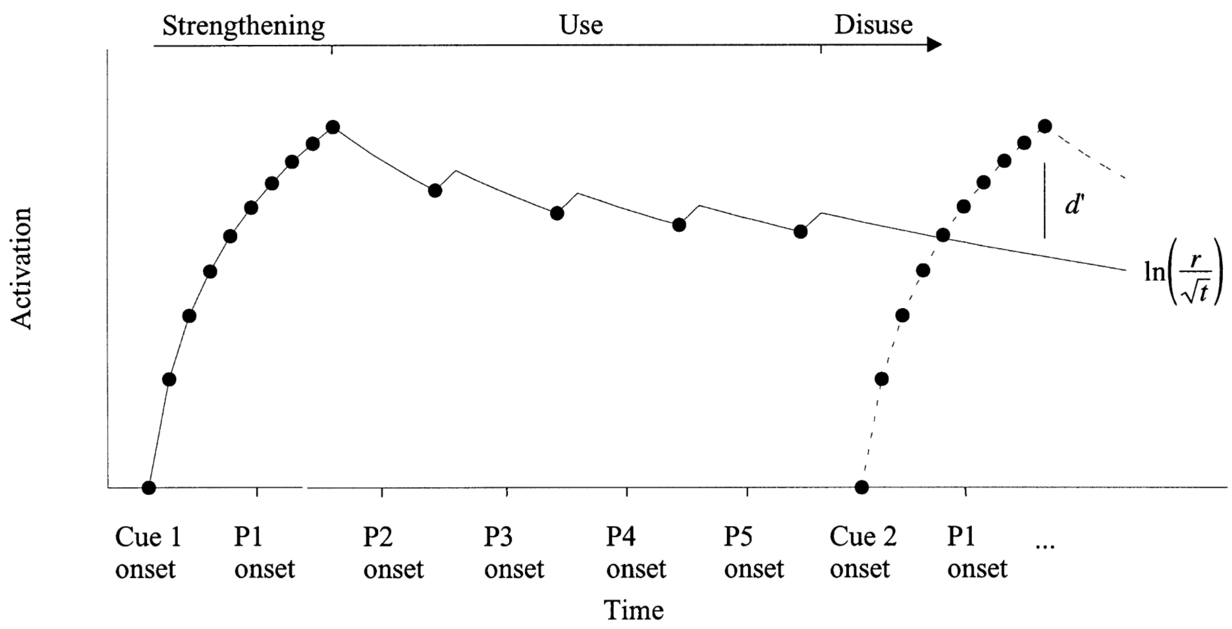


Fig. 6 Task set activation over time, from onset of an instruction (Cue 1) through five trials (P1 to P5). Task-set retrievals are marked by filled circles. Activation ¼ ln r= ffiffi t p , with r=retrieval count and t=time since encoding. During strengthening, retrievals are massed (every 100 ms). During use, retrievals are spaced (every 600 ms), each boosting activation but not enough to offset the downward trend. During disuse, retrievals stop. Because of decay during use, d' is positive once the next task set (dashed ink) is fully encoded, as in Fig. 1