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Galton's number

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Galton posed the following question: What is the number of accessible autobiographical episodes in memory? The answer to this question implicates a number of issues in the psychophysics of time and memory. We had found (Crovitz & Schiffman, 1974) a surprisingly fertile equation ($\log f = \log b - a \log t$) relating the number ($f$) of episodes accessible at any given time (t) ago. We discuss this log-log law of memory; we differentiate it, exposing a form of Weber's law in the time domain; and we integrate this equation, which allows us to answer Galton's question and make other empirical predictions.

Galton, in his famous walk (Crovitz, 1970), became aware of how swiftly events that had been experienced "sank and appeared to be utterly drowned in the waters of Lethe." His observations on the evanescence of episodes in memory startled his contemporaries, as they did himself, when he found himself compelled to write, "our supposed recollections of a past life are, I believe, no more than that of a large number of episodes in it, to be reckoned in hundreds or thousands, certainly not in tens of hundreds of thousands, which have escaped oblivion" (Galton, 1907, p. 139). Thus Galton raised three interesting questions pertinent to the psychophysics of memory and time ago, which we shall attempt to quantify. First, how do episodes "recede into Lethe"? Second, how does the Weber function of frequency relate to the Weber function of time ago? And third, what is the number of episodes that escape the fate of inaccessibility? Thus, in the present paper, we intend to show (1) how the 1974 equation is the answer to the first question, (2) how presenting this equation in its differential form makes a Weberian psychophysical memory statement, and (3) how integrating this permits an answer to the question of the number of episodes accessible from any time-ago interval.

In our previous paper (Crovitz & Schiffman, 1974), we investigated the question of the speed of disappearance of episodes from accessibility. Our sampling method was to give subjects a set of common nouns and ask them to recall a personal memory from their lives that they associated with each noun; then, to estimate how long ago the episode had occurred. The result was a surprisingly orderly set of frequencies of recalled episodes at time-ago intervals. The analysis of these data led to a linear log-log function, as follows:

$$\log f = \log b - a \log t, \qquad (1)$$

where a is the slope, $\log b$ is the intercept of this linear function, and t is the time ago in hours.

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In this paper, we intend to exploit this equation by entertaining the notion that this equation is not merely an empirical fit between two variables, but also possibly a theoretical expression of a more general underlying process.

Equation 1 can be rewritten, using antilogs as a power function, as follows:

$$f = bt^{-a}. \qquad (2)$$

It has developed that this relationship, when expressed in this power function mode, is familiar in psychophysics and has been replicated numerous times in the memory domain (Rubin, 1982).

When cast in the form of Equation 1, the differentiation leads to an extremely interesting psychophysical function in the memory domain:

$$\frac{df}{f} = -a\frac{dt}{t}. \qquad (3)$$

This states that the Weber-like change in episodic frequency is negatively proportional to the Weber-like change in time-ago interval. This version of Weber's function in the time domain exposes a relationship between changes in access frequency and changes in the passage of time.

Suppose we were now able to count the number of memories in discrete intervals of time ago, and then add them up over any specified interval. But this would roughly correspond to integrating Equation 2 over time-ago intervals. Multiplying both sides by dt and integrating, we find

$$\int f dt = \frac{b}{(1-a)} t^{1-a}. \qquad (4)$$

With this equation in hand, we have now positioned ourselves to obtain the number of accessible episodes between any time intervals, given a valid estimate of the coefficient $[b/(1-a)]$, which turns out to be the number of events recollected from 0 to 1 h ago.

Equation 4 gives a method of calculating the expected number of episodes in any time-ago interval, given the number of episodes remembered from the past hour, and the slope. The slope that we and others have found is about $a = -0.8$. According to this method of calculation, with $a = -0.8$, if you recollect 20 events from the past hour, you will recollect $20(20 \cdot 365 \cdot 24)^{.2} = 224$ events from the past 20 years. Given this case, how many episodes would be expected from between 60 and 90 days ago? This calculation would be the total from the present through 90 days ago $[20(24 \cdot 90)^{.2}]$ minus the total from the present through 60 days ago $[20(24 \cdot 60)^{.2}] = 7.23$.

Two provisos should be emphasized. First, we are dealing with everyday psychological episodes. Each episode is a complex entity composed of such macroscopic features as who was involved, where the event took place, what was involved, when the event occurred, and perhaps additional details and emotions (Wagenaar, 1986), as well as the appropriate method for elicitation. Second, there may be age effects and time-interval limitations such that, for example, the function becomes nonlinear after 20 years ago (Rubin, Wetzler, & Nebes, 1986).

If we then take Equation 4 as a theory of the number of accessible episodes that can be recollected over any time ago, with $a = -0.8$, and if the number of episodes recalled from now to 1 h ago = 20 and we limit ourselves to 20 years, then 224 is Galton's number—that is, the total store of accessible recollections of events over the past 20 years. We now have invited empirical tests and created a theory of the psychophysics of time. The apparent radical loss in accessibility is nothing but a natural consequence of the logarithmic behavior of memory when it is viewed as episodes over log time. This contrasts with alternative views of storage capacity in terms of bits (Landauer, 1986). The difference in the estimated number of memories lies in the difference in resolving power of the units in question: bits versus episodes.

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