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P.A. Hancock

The Time of Your Life: One Thousand Moons

"All my possessions for a moment of time" (Queen Elizabeth I with her dying breath.).

ABSTRACT

The present work deals with four themes that relate to the problem of aging and time. They include questions of allometric scaling, the novelty of experience, the change in perception of time with age, and the certainty of death. Featured in each of these themes is the prominence of time and the manner in which poetic, scientific, and technologic facets of each theme are interwoven. The overall argument serves to dispel the chronometric dominance of time versus its behavioral reality.

Thematic Statement

"Lamentably, there is too short an interval between the time when one is too young and the time when one is too old." Charles de Montesquieu (1689-1755).

It is poignant truth that our lives start with a period of which we subsequently have little remembrance and ends, for most of us, with a slow decline during which much time is given over to recapturing the past. These powerful life effects are not illogical

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given that for the very old, the future holds little in the way of expectation, and for the very young, their present lacks the structure through which to organize experience. Between this search for the meaning of pattern and the pattern of meaning lie the years of physical, mental, and social power beset with the reliquaries of impotent childhood and the specter of disenfranchised old age. Over-riding these progressive ages of development is the leitmotif of human consciousness - certain mortality. Of all living things that share our planet, it is we alone who have a clear and unequivocal knowledge of our own individual and inevitable demise. If only this spatial recognition of certain demise were accompanied by a similar certainty of the timing of the actual event, we could perhaps collectively abandon ourselves to a fatalism, anathema to the cheerful dark optimism portrayed by our escapist media. At the center of this very human question lies the one essential arbiter - time. Quite illogically, we have come to accept perhaps the most facile of all lies concerning time. That is its overmastering immaleability. Among the founding fathers of the religion of science, this wonderfully comfortable and comforting conception of the Universe as a clockwork mechanism was anodyne to the black fog of then existing ignorance. Today, we are little better off, seeking to hold hard to absolutes such as the velocity of that which lights our way. But in so doing, we can at last, with some temerity, sacrifice one absolute that has plagued us not only since the mechanists, but for centuries pre-dating their Grecian forebears. The mastery of time. Accompanying this fundamental change in our view of time must come a similar change in our understanding of what is aging, and thus life itself.

I have asserted that time is the essence of aging. The present work's structure flows from this observation. There are four central themes. For each theme, I illustrate that the poetic precedes and frequently supersedes the scientific in richness of explanation while the scientific represents the formal foundation of the technological perspective. For, after all, the purpose of understanding is not merely to know the world but to change it. I endeavor to use these observations to elevate temporal considerations to their rightful preeminence (and also see Fraser, 1987; Hendricks & Hendricks, 1976; and Schroots & Birren, 1990). The sequence in which the four identified themes are approached is the inverse order of their relative importance. They are; i) the allometric scaling of a lifetime; ii) aging and the novelty of experience; iii)

the changing perception of time with age and; iv) the sure and certain knowledge of our own individual demise. The conclusions to be drawn from these themes are of central importance to an understanding of human aging in a world where technology is rapidly becoming our theology (Hancock, 1995).

The Allometric Scaling of A 'Life' Time

> And remember that the companionship of time is but of short duration. It flies more quickly than the shades of evening. We are like a child that grasps in his hand a sunbeam. He opens his hand soon again, but, to his amazement, finds it empty and the brightness gone. (Yedaya Penini).

For all of the themes, I look first to the poetic, then to the scientific, and finally to the technologic. Not only is this an historically and chronologically correct progression but it is one that commences with the *ideal* and evolves toward the *actual* (see also Hancock, 1995). The first theme is the allometric equivalence in life. I use this to illustrate the unity of existence and to emphasize the importance of 'life' as lived, and life as viewed in retrospect, compared with arbitrary measures of existence derived from sidereal 'time.'

Poetic Pronouncements on Allometry

With respect to allometry, one poetic insight comes from William Oldys (1696-1761) in his reverie concerning a fly (see Quiller-Couch, 1961, pp. 515-516). His central concern is with the comparison of life, which centers on the 'length' of a lifetime and in his poem 'On a fly drinking out of his cup,' he ends this comparison between human and insect life with:

> Make the most of life you may,
> Life is short and wears away.
>
> Both alike are mine and thine
> Hastening quick to their decline:
> Thine's a summer, mine's no more,
> Though repeated to threescore.
> Threescore summers, when they're gone.
> Will appear as short as one!

Oldys is making two trenchant points that are intimately related. The first is the equivalence of life *as lived*. The second is the equality of life *in retrospect*. By reference to a simple fly and by observing a kinship in action, Oldys is pointing to the unity of living things. The clarity is emphasized by the juxtaposition of man, viewed as the height of creation, with the fly, seen as the least of nature's creatures. In his poem 'The Fly,' William Blake (1757-1827) also uses the same observation to accentuate this contrast - commonalty dualism to compare God's deliberation of each respective creature, man and fly. Whether Blake was inspired by Oldys, I cannot say. Let us hear from Blake's (1794), '*Songs of Experience*':

> Little Fly, thy summer's play
> My thoughtless hand has brush'd away
> Am I not, a fly like thee?
> Or art thou not. a man like me?
>
> For I dance, and drink, & sing,
> Till some blind hand shall brush my wing.
> If thought is life and strength & breath
> And the want of thought is death;
> Then am I a happy fly,
> If I live or if I die.

That Oldys could distill, the allometric equivalence of life *as lived* solely from observation, is instructive. That he proposes comparable equivalence of life *in retrospect* is impressive and argues the efficacy of unalloyed reason and intuition (and of course see Kant, 1787). I submit that this early assertion is clearly as valid a comment upon the phenomenon as the subsequent scientific statements to which I now turn.

The Scientific View of Lifetime Allometry

Let us hear from the modern scientist on allometry. To quote Calder (1984):

> Using maximum life span, rather than absolute time, as the end point of a size-dependent physiological time scale, it appears that each life comprises about the same number of physiological events or actions; in other words,

> each animal lives its life faster or slower as governed by size, but accomplishes just as much biologically whether large or small.

That is, the lifetimes of animals are equivalent in terms of physiological events. Oldys earlier insight allows us to experience this comparison on an empathic level, in which we co-identify with man and fly. There is, however, a deeper insight here that is brought out by neither poetic nor scientific pronouncements. It is the ultimate reality of *life* in comparison with the arbitrary dimensions of time and space (and see Gibson, 1975). A relevant insight of Locke's (1690) is the difference between space and time on the one hand, and expansion and duration on the other. Although they are treated synonymously in the world of physics, the two are different in more than the facile distinction of measurement properties. The true measure of *duration* in ecological mechanics (as compared to quantum and celestial mechanics; see Shaw & Kinsella-Shaw, 1988) is therefore a *lifetime.* As physics has no referential frame to deal with this biological construct (Gibson, 1975), behavior and consciousness have been distorted to conform to the artificial uniformities of space and time as common matrices. For the clock, simultaneity, succession, duration, and memory have no meaning, for living things, they are the very stuff of life.

Given this observation that we each live a 'lifetime,' it is instructive to look at human longevity as detailed in Figure 1. As can be seen, life span has apparently more than doubled in a mere three and one-half centuries. But do we have any more *life*? In the facile sense of sidereal time the answer is of course yes. The number of moons (approximately one thousand for average current longevity in the Western world) seen by any one individual living seventy-five years is evidently greater than that of an individual living thirty-five years. However, I propose here that there is an *equifinality* of the behavioral lifetime of each individual, couched in their respective historical epoch. That is, each individual lives a full 'lifetime.' As equivalence of life, as lived, is perpetuated throughout the animal kingdom all organisms which come to maturity live this 'lifetime.' As a consequence, the one real tragedy of life is that of premature death in the young.

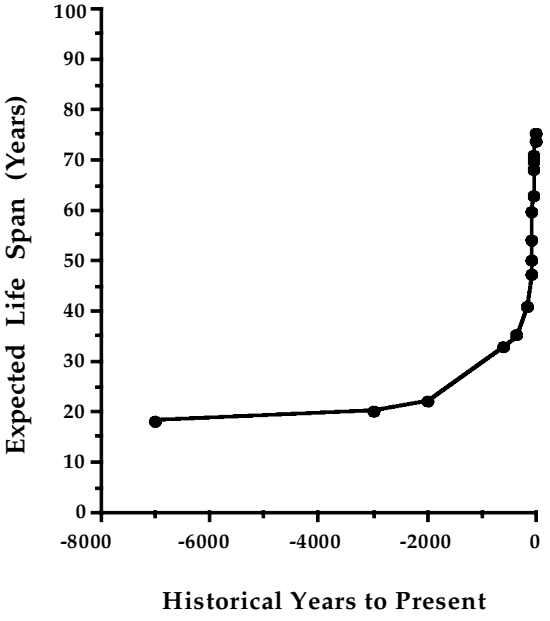

Figure 1: Increase in lifespan over recorded history. Data from multiple sources including Lerner (1976); U.S. Senate Special Committee on Aging (1987-1988). At first, the graph looks startling. The growth of longevity appears to mean that human beings will be virtually immortal within a few decades. Alas for statistics (Huff, 1954). The problem here is the use of *average* lifespan. Let us consider the situation of ten individuals. Eight of the individuals live to the age of 60 but unfortunately two of the individuals die at the age of 1 from some disease. The *average* lifespan of this group comes out to 48.2 years. Now let us suppose that one of the two unfortunate children had not died in childhood but lived to 60 like their peers. Now the *average* life-span has increased to 54.1 years. This looks a staggering increase of 5.9 years. Although nobody in the group lives to be older than sixty, the implication from the average is that each *individual* has more years of life. Alas for averages. Obviously this is only the one factor of infant mortality rate and many others affect lifespan (Riley, 2001). In actuality, we have added relatively little to the lifespan of individuals who reach maturity (Lewontin, 1991). Those hoping for immortality should, therefore, not look to longevity graphs such as the one illustrated.

The Practical Aspects of Allometry

Are there any practical ramification to these allometric observations? I submit that there are. If, putatively, time is 'all you have,' all of design and technology comes down to the support of time. Many useful observations on the practical aspects of time have been made by Servan-Schreiber (1988) in an excellent little book. However, I want to discuss briefly what these observa-

tions on time mean specifically for future design. I suggest that much of our present concerns for aging derives specifically from our progressive fracture of allometric scaling. We are learning to design for the support of our years of continued life but not, unfortunately, for the invigoration of those added years. Some allometric pronouncements indicate that 'natural' human lifespan is 27 years (see Yates, 1988). Through technical intervention, we have expanded our life some three-fold beyond our 'natural' animalistic 'lifetime.' We have managed to manipulate the boundary of the allometric constraint, but what is the price for this freedom? I suggest that in addition to expanding longevity, we have *diluted* life as well. We have come to scale or dilute the concentration of life spread over the greater number of expected years. This increase in the number of years also acts to render 'death' a more fearful event since its approach is at a 'slower' rate, a phenomenon I shall return to later. Human beings seek novelty in experience and to those who sustain novelty in experience these behavioral hazards of aging are diminished. However, this novelty is had at a cost. Today, supposed novelty comes in the pre-packaged and passive forms, provided by our soporific media. We experience unusual circumstances only at a distance and vicariously at that. Our price of novelty in these terms is, paradoxically, a diminution of life (Postman, 1986).

Therefore, the role of design is to excite, to empower, (Illich, 1975) to encourage, and to permit exploration of challenging and exotic 'environments.' These may well be physical environments but they can as easily be informational environments, where the challenge is cognitive rather than physical. The critical contemporary technology in this respect is the computer. An artifact, like a computer, encourages consumerism but does not prevent creativity. However, the software that accompanies such systems almost inevitably does. Under the guise of some 'freedom,' most commercial software constrains the operator and permits a limited and largely uninspiring form of interaction. Despite the obvious protests that this will raise, hardware can be a 'convivial' tool. Software, even bare operating systems, rarely exhibit comparable conviviality (Illich, 1973). What the technologist should seek to achieve is the enhancement of the experience of life. As individuals grow older, this challenge becomes greater, since older individuals have already seen much of what life has to offer. Thus design should permit creation, so that we have, not 'users' of systems, but both 'creators of' and 'creators in' systems. For most older

individuals the process of creativity has been stifled for such an extended period that they forget how to *'make it new*.' Many doubt that they were ever creative in the first place, where the memory of childhood play is long gone. Thus the first step in design for aging is in capturing and re-capturing the novelty of experience.

Aging and the Novelty of Experience

Make it new (Proust)

The Primacy of Youth

The primacy of youth is a perennial theme of literature and poetry, including Wilde's sad observation that *'youth is wasted on the young*.' The epitome of youth and time is given by Robert Herrick (1591-1674) in his poem 'To The Virgins, To Make Much of Time' (Quiller-Couch, 1961, p. 274) for which the first, well known verse begins:

Gather ye rosebuds while ye may,
Old Time is still a-flying;
And this same flower that smiles today,
Tomorrow will be dying.

We are reminded of the same concern in Charles Kingsley's (1819-1875), 'Young and Old' (1863) which starts:

When all the world is young, lad,
And all the trees are green;
And every goose a swan, lad,
And every lass a queen;
Then hey for boot and horse, lad,
And round the world away;
Young blood must have its course, lad,
And every dog his day.

The primacy of youth is also echoed in A.E. Housman's stanza from his 1896 'A Shropshire Lad.'

> Ah, spring was sent for lass and lad,
> Tis now the blood runs gold,
> And man and maid had best be glad
> Before the world is old.

Each of these suggest that aging is, in part, a process in which fewer and fewer things are 'new' and it is the 'newness' or novelty in experience that combats aging in the mind. Consider the following from Marcus Aurelius (121-180):

> Principles can only lose their vitality when the first impressions from which they derive have sunk into extinction; and it is for you to keep fanning these continually into fresh flame. I am well able to form the right impression of a thing; and given this ability, there is no need to disquiet myself. (As for things that are beyond my understanding, they are no concern of my understanding). Once learn this, and you stand erect. A new life lies within your grasp. You have only to see things once more in the light of your first and earlier vision and life begins anew.

One, perhaps anecdotal, story concerning the actor George Sanders is that he left a suicide note that stated poignantly 'I'm so bored.' I think he meant that life had nothing left for him, there was no novelty. He could not, in Proust's terms, 'make it new.' It is in this facet of life for the aging individual that I think the practical applications of design of technology can play such a role. As this is a speculative work, I feel free to speculate that the acknowledged longevity of eminent mathematicians might well be related to their renewal abilities found in worlds of their own creation. In this I assert that there is a connection between the quality of mental existence and longevity. I am sure more positivistic scientists will be skeptical about such a proposition. However, consider one simple physical aspect of aging. It is clear that aging is often accompanied by a restriction in physical mobility. Such restrictions constrain the opportunities to discover and experience novel conditions. That there may well be a cognitive analog to this restriction should be recognized as a feasible possibility.

Negentropy: The Science of Novelty

> Nihil sub sole novum (There is nothing new under the sun).

The potency of novelty can still be had in old age. For example, in work on memory and aging, one study had individuals engage in new experiences such as eating fruits that they had not eaten before. Upon testing, it was found that recall of events of the day which include this 'new' experience was better than days on which no novel events occurred. If these observations connote anything at all, they represent the fact that 'aging' in the behavioral sense, is critically dependent upon novelty, newness, and difference in experience. Those who encounter novelty, those who seek difference, those who are able to 'make it new' do not suffer the consciousness of aging in the same fashion as their peers who do not or cannot. For those who cannot, the process, could be described as dysdifferentiation. I use this 'jargon' word purposely in asking the reader to consider the following quotation from Yates (1988):

> Cutler (1983) views the aging process as largely one of dysdifferentiation, the slow progression of cells away from their proper state of differentiation. Longevity of a species is then determined by processes acting to stabilize the cells' proper state of differentiation against the de-stabilizing effects of by-products of energy metabolism. Among these threatening by products are toxic free radicals arising from oxygen metabolism. To Cutler it appears as if a species' aging rate is proportional to its specific metabolic rate.

What I want to note here is that dysdifferentiation is used at a cellular level to describe the process of aging. This observation suggests that difference and distinction are thus valuable at all 'levels of analysis' as mitigation of the aging process. The concept that underlies differentiation at all levels is information and entropy.

In essence an open system, life is negentropic in seeking to maintain order in the face of disorder. The tenor of the present remarks is that order is represented by information manifest as selective differentiation. *The breakdown of that ordering, at each level of analysis, is representative of aging. The dissolution of that order, at each level of analysis, is death.* What I hope I have shown here is that poetic pronouncements provide this enlightenment, especially at the

behavioral level, as much as scientific pronouncements. The bridge between renewal and death is our appreciation of time. Consider the following from Butler (1903):

> Every change is a shock; every shock is a pro tanto death. What we call death is only a shock great enough to destroy our power to recognize a past and a present as resembling one another. It is the making us consider the points of difference between our present and our past greater than the points of resemblance, so that we can no longer call the former of these two in any proper sense a continuation of the second, but find it less trouble to think of it as something that we choose to call new.

Virtual Innovation

I said at the beginning of this work that 'given that for the old, the future holds little in the way of expectation,' that certain aging affects are not illogical. Now, I want to question why the future has to be so predictable for the old. While individuals were constrained to the same location, as they were in most primitive agrarian societies, time was emphasized as a cyclic process (see Fraser, 1987) and knowledge and skills of the older members of society were valued since alternative sources of information were not easily accessible. However, as societal mobility has increased, the informational value of the knowledge of the old has diminished greatly. Also, as personal mobility decreases in older individuals and the novelty of living is sequentially reduced, the living conditions of the aged can come to approximate those of perceptual deprivation. Perceptual deprivation is the reduction in the patterning of stimulation presented to individuals, where patterning, novelty, and information are interlinked constructs. Studies on both perceptual and sensory deprivation conditions show ubiquitously that extended exposure leads to radical behavioral dysfunction (Zubek, Pushkar, Sansom, & Gowing, 1961). And yet, this is what we condemn a large percentage of our older population to; by design. Thus, for older individuals living in a chronic state of deprived perceptual stimulation it is unsurprising that they have trouble 'making it new.' As experience accumulates, the world threatens to become a perceptual ganzfeld where the individual has 'seen it all before' and little is available immediately to mitigate ennui. Can technology change this lamentable position where all novelty is sucked from life. I suggest it can. In particular I see the

confluence of two forces as particularly important. The first is the theme of education through the lifespan and the second is the use of virtual reality to make those learning experiences meaningful and more critically, novel.

Much has been said about virtual reality in both the popular and scientific literature. Unfortunately, much more of it is virtual than real. There is a recent assessment of the state-of-the-art by the National Academy of Sciences that provides a comprehensive review of current developments (Durlach & Mavor, 1995). Clearly, the great advantage of virtual reality is the ability to manipulate spatial and to a lesser extent temporal boundaries. The opportunity is to free individuals from the constraints of here and now and by manipulation of the sense of presence (Heeter, 1992; Singer, Bailey, & Witman, 1994), to place them at will in other times and places, or in environments that represent pure invention. The opportunity seems almost without limit and it is this excitement and seduction that has attracted so much attention from both the scientific community and the general public alike. Unfortunately, the present state of development does not match these expectations. Complex graphic worlds are difficult to program and computationally expensive to sustain, especially in 'real-time.' Many current systems, that show unexpected gains in progress, finesse such problems by presenting 'canned' environments with limited ranges of interaction. Such systems are useful for entertainment but do not permit the generative activities advocated here. Problems still abound. Head-mounted display technologies are still poor and time lags in tracking head movements can induce VR sickness (Biocca, 1992). If worlds are insufficiently complex, virtual boredom can quickly set in, as all the options of that 'world' are quickly exhausted. Much still needs to be done to make the promise a reality or even a virtual reality (see Durlach & Mavor, 1995; Kozak, Hancock, Arthur, & Chrysler, 1993). However, if achieved, the limits placed on individuals with respect to mobility are quickly fractured and tele-presence in our own and created worlds becomes practicable. VR is a critical weapon in the gerontechnologists armory and designers need to use creative capacities to generate challenging worlds. Indeed, what greater joy could a designer have then to design a whole 'world.' One of the reasons to consider the importance of novelty of experience is the way in which the content of experience relates directly to the perception of the speed of passage of time in that experience. It is this variation in the rate of perceived duration that is the next theme for consideration.

Changing Perception of Time With Age

The River of Life

I can find no better example, in either the poetic or scientific literatures, to express the phenomenon of the changing pace of time with aging than Thomas Campbell's (1774-1844) 'River of Life.' It is such an important observation that I give the first three verses here complete:

> The more we live, more brief appear
> Our life's succeeding stages:
> A day to childhood seems a year,
> And year's like passing ages.
>
> The gladsome current of our youth
> Ere passion yet disorders,
> Steals lingering like a river smooth
> Along its grassy borders.
>
> But as the care-worn cheeks grow wan,
> And sorrow's shafts fly thicker,
> Ye stars, that measure life to man,
> Why seem your courses quicker?

Campbell's work is special in so many ways (and see Beattie, 1849). First, it describes, in a most economical and direct manner, the increase in the rate of perceived time with age. Were this all, it would be important, but Campbell offers much more than this. In the full poem, Campbell presents a reason (that is an hypothesis) for this apparent speeding. It is based in the actions of a beneficent deity, who establishes the duration of each phase of life and accords perceived time appropriately. Death is given as a blessing to those who have outlived their friends (and see also the final verse of Kingsley's *Young and Old*). In our mechanistic age, we would deny the validity of such a claim (although not necessarily on empirical grounds). However, we cannot deny that Campbell captures a basic observation of human existence and he offers an explanation for it. Thus Campbell articulates not only what Aristotle would call 'efficient' cause for aging, that is the physical causality we commonly

recognize today, he also offers a 'final' cause for aging, that is a reason *why* this occurs. While science frequently offers efficient cause *forms* of explanation for phenomena, it is rare that any final cause is presented in the same hypothesis (and see Popper, 1983). But further, Campbell challenges us to ask whether we would change this acceleration, if we could? As such, his contribution is validated as observation, as hypothesis, as explanation, and as interrogation.

The Causal Search

In one of the landmark studies in the perception of time Hudson Hoagland (1933) concluded with a statement about the time and aging. He quoted the work of Nobel prize winner, Alexis Carrel (see Carrel, 1931).

> Carrel concludes that physiological time is determined by a succession of irreversible changes in the system cells-medium and can be measured and expressed in specific units. It varies progressively in a way that physical (astronomical) time does not. To illustrate the apparent speeding up of physical time in old age, he suggests the analogy of two trains running in the same direction on parallel tracks, one representing physical time and the other physiological time. At first the trains are running at equal speeds and then one (physiological time) slows up. The other continues as a uniform speed so that to passengers on the decelerating 'physiological train' it appears to go faster.

In a similar vein, let us hear from a more recent source with this quotation from a modern text on time perception by Cohen (1967).

> It is often remarked that as we grow older the years seem to pass more quickly. What does this mean? As we get older, the metabolic rate slows down, and this presumably has an affect on apparent duration similar to the hypothetical effect of a reduced temperature. That is, calendar time would seem to pass more quickly because subjective time is slower. On this basis, when we look back on the previous subjective year, it will seem to have passed more slowly, in terms of calendar years than the subjective year just completed, having more subjective units per chronological unit. Or, to put it the other way round, as we grow older, there is a decline in the number of subjective years per calendar year. We do not however, contradict

> ourselves when we say the years pass more quickly, i.e., there are more calendar years per subjective year. To illustrate: suppose a 15 year old boy is told to tap once per "year." Because he is young and has a relatively high metabolic rate, he will tap say five time per calendar year. Forty years later, when he reaches the age of 55 he will, on the same instructions, tap, say, once in each calendar year. (Cohen, 1967; pp. 22-23).

A number of mathematical descriptions have been advanced to capture this phenomenon of temporal acceleration with age. Janet (1877) proposed a linear increase in the speed of subjective time with age (see also Fraisse, 1963). LeCompte DuNouy (1937), based his curvilinear function about subjective time change on observations of the rate of wound-healing in young men that he had observed during the First World War. More recently, Lemlich (1975) postulated an alternative curve using memory of past events as a basis for understanding temporal acceleration rate (see also Joubert, 1983, 1984, 1990). All of these relationships are illustrated in Figure 2.

It is important to distinguish the different theoretical foundations of these proposals. Janet's explanation is based primarily upon the physics of aging. DuNouy's formulation, in contrast, is heavily physiological in orientation. Lemlich's position is founded upon an approach from psychology and human cognition. While these differing perspectives generate different functions to describe how the phenomena occurs, each is in fundamental agreement that perceived time does accelerate with age (see also Nitardy, 1943).

The perception of the temporal world is typically divided into three durational 'windows' (see Block, 1990). First, there are measures of succession and simultaneity that are in the order of milliseconds. Second, there are measures of duration that are in the order of seconds and minutes. Finally, there are measures of temporal orientation in the order of days, months, and years (see also Allan, 1979; Iberall, 1992; Poppel, 1988). With respect to Janet's assertion, we would expect that any physical change would affect the perception of all time scales. In contrast, DuNouy's physiological approach would favor a predominant effect in the order of seconds to minutes. For Lemlich, time perception changes with age rely on the function of memory (predominantly long term memory) and would therefore accentuate changes in time orientation in the order of days, months and years. The present evidence for change in simultaneity with age is equivocal. Studies cannot partition out the perceptual

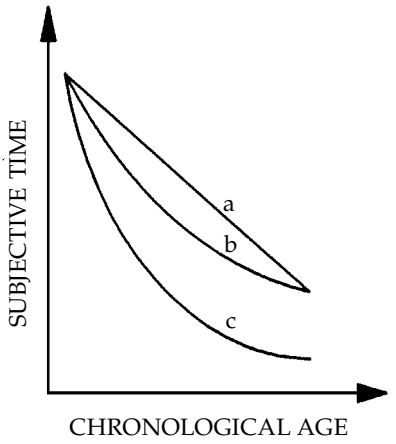

Figure 2: Proposed relationships between the perception of time and chronological age of the observer. Equation (a) follows Janet (1877) and takes the form: y = a-bx, where a is the intercept and b is the slope. Equation (b) follows Lemlich (1975) and takes the form $y = \sqrt{x/x'}$, where x is the observer age in years and x' is the duration in years of the event memory. Finally, equation (c) is from DuNouy (1937) and takes the form y = 1/x. The central difference between each formulation is how the increase changes. The figure plotted uses arbitrary comparative ages, hence individual formulations have to be derived from the equations given. Each relationship asserts the objectivity of sidereal time, expressed as chronological age. In this, the formulations follow much of science in assuming time to be a linear, immaleable dimension in the Newtonian sense. This assumption is challenged in the present work.

from motor effects. Older individuals do react more slowly and the temptation is to place this effect in a central 'clock' type mechanism (cf., Salthouse, Wright, & Ellis, 1979). There is now collective evidence to support the contention of a change in duration perception and temporal orientation with age (see Block & Zakay, 1994; Block, Zakay, & Hancock, 1998; Hancock, 2002).

The whole basis for the assessment of these proposals is, in one sense, fundamentally flawed. This is because sidereal time is treated as objective reality or 'real' time, while difference in perceived time is viewed as a distortion or an error. For example, in Carrel's (1931) statement, the trains at first travel at the same speed. This implies that time is 'right' when we are young and therefore distorted or 'wrong' when we are old. This is just one example of the problems encountered in the relativity of time. Time (and space) are arbitrary matrices that we impose upon experience to provide order and mutually acceptable frames of reference. However, they are not 'correct' in an

unquestionable way. We should be assiduous in our challenge to the imposition of an arbitrary referential frame, regardless of its social utility. In essence, we need to redeem time.

Let us compare the foregoing comments with Yates's (1988) observation:

> Intrinsic time is created by biological processes as an emergent property of their non-linear dissipative dynamics, leading to the result, . . . that the intrinsic biological significance of a unit of external time cannot itself be constant but must change with chronological age. For instance, if we rescale time so that two extrinsic time intervals are similar in that the probability of death of an organism (intrinsically determined) is the same for each of them, then the length of extrinsic time intervals so matched progressively shrinks as the organism ages.
>
> External time and intrinsic time for an individual are coupled through circadian (and perhaps other) endogenous rhythms that can be entrained by geophysical and social rhythms. This, I believe, is the chief function of many of the so-called biological clocks - to connect intrinsic and extrinsic times. (But not all intrinsic time is entrainable by periodic processes in external time).

Consequently, the true temporal physics of life, is a lifetime.

Glory Days

> Golden lads and girls all must, like chimney-sweepers come to dust. (Shakespeare)

The theme of novelty with youth is ubiquitous in literature. Why is it that the years of late adolescence and early adulthood are viewed in retrospect as a 'golden age.' Why does this era of life form so much of the subject matter of fiction, popular music, and motion pictures? I think that, in addition to the obvious facts such as adolescence and sexual maturation, there is an important temporal component. As we have seen, the perceived rate of duration accelerates with age. Regardless of the theoretical foundation that underlies this phenomenon, all positions agree that this acceleration is continuous. That is the change is gradual and uninterrupted rather than punctate or

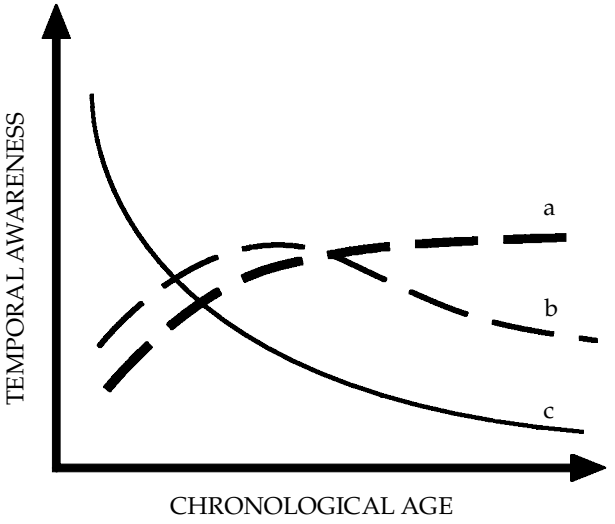

Figure 3: Composite plot of temporal orientations representing the maturation of temporal perspective and the diminishing perception of time with age result in a maximum during early adulthood. The line (c) represents the change in time perception as previously discussed. The line (a) represents the maturation of temporal faculties. The composite line (b) represents the lifespan course of time appreciation.

discontinuous. However, while time perception accelerates, our *knowledge* of the structure of time is developmental and grows in the years of childhood (Piaget, 1946). For example, infantile amnesia means few of us can remember our first year of life and it has been suggested that the child's conception of time matures into the early teens. In consequence, we have two basic functions, one being an acceleration of time, while antagonistically we have a maturation of the temporal perspective. I have combined these functions in the following illustration.

This is a generic illustration since the precise formula for any of the functions is not available. For example, for the perception of time in passing (curve c), Block, Zakay, and Hancock (1998) have presented a meta-analysis that suggests interesting variations with age. Curve 'a' is a speculative but defendable function that is based on developmental perspective (Levin & Zakay, 1989; Freidman, 1986). The composite function, curve b, is supportable and identifies a 'level' of temporal awareness in retrospect. It represents an attempt to understand our temporal view through life, a topic explored in greater

detail by Rubin and his colleague. (Rubin, Rahhal, & Poon, 1998; Rubin & Schulkind, 1997). Note here then that our greatest temporal awareness occurs in these final years of adolescence and early adulthood. It may be why we spend so much time later in life trying to recapture lost youth.

Practical Synchronization

The codification of time is a social contract. Arbitrary reference frames in space and time allow one individual to interact with another. In this way, space and time are a form of language. When such reference frames become ossified and deified, they are elevated in both the personal and social consciousness to the status of 'reality.' We rarely stop to question this reality (but see Schroots & Birren, 1990). To break this impasse, we have to return to the reason time was codified in the first place - social communication. At its essence, time is used to *synchronize* the actions of individuals. In this we have to extend communication beyond human to human relationships and today consider communication as a central component of human-machine relationships also (Hancock, 1997). It is in this way that an understanding of the dynamics of personal time enter the design process. Elsewhere, I have advocated the principal of 'functional synchronization' as the organizing principal that mediates human-technology interaction (Hancock & Chignell, 1987). This position recognizes the ascendancy of an individual users' time over the arbitrary clock reference. While the computer continues to use time in a Newtonian fashion (i.e., a regular central clocking mechanisms), there is no longer any reason that the human operator should remain a slave to this sterile conception (see also Marshburn, 1989). For design, this means seeking the individual temporal preferences for the presentation of information. At the forefront of examples of designing for individual time, rather than social time, is that for older users.

In real-world conditions, individuals have to interact with each other. Older individuals try to regulate that interaction by placing constraints on their own activity. Driving is a pre-eminent example. Older drivers restrict their driving during night-time, they are less likely to go to unusual or unknown destinations, and they avoid complicated and demanding traffic situations (Caird & Hancock, 2002). Despite this self-regulation older drivers, aged fifty-five and above, are over-represented in accidents where they are asked to

synchronize their actions with other individuals. These problems take the form of increased accident rates in maneuvers such as the left turns, merging, and overtaking (Transportation Research Board, 1988). While the older driver and the younger driver may each be proceeding at their own individually preferred speed (tempo), the disparity in their respective perceptions means that there is a dangerous differential in the velocities of their two vehicles. It is important to note that neither younger nor older driver is 'right' they are both correct within their own temporal context. The role of the machine in this situation is to become a buffer between these two disparate 'times.' Many design options are possible. They range from warnings and advisories to automation over-ride, each of which have been proposed under the new Intelligent Transportation Systems (ITS) initiatives (Hancock & Parasuraman, 1992; Hancock, Parasuraman, & Byrne, 1995). This is only a single exemplar, however, the principle of 'temporal design' should be incorporated to all facets of human-technology interaction across the life-span. Indeed, from the curves presented in Figure 3, it is clear that this issue is as important for children and their interaction as it is for their parents and grandparents. Ergonomics is the applied science that seeks to elevate the individual to the pre-eminent place in design consideration (see Oborne, Branton, Leal, Shipley, & Stewart, 1993; Parasuraman & Mouloua, 1995). This development of adaptive human-machine systems should focus not only upon the physical anthropometrics and cognitive characteristics of the individual but should emphasize time as a primary dimension of existence.

Concord and Discord

Its always useful to remember that the poetic and the scientific are not always in accord, especially when we explore the scientific beyond the realm of behavior and extend our discourse to the very large and the very small in the terms of celestial and quantum mechanics. Contrast the following observations.

> Time is a sort of a river of passing events, and strange is the current. (Marcus Aurelius)

> Time is but the stream I go a-fishing in (Henry David Thoreau)

versus

> You're stuck with a grotesque and absurd illusion . . . the idea of time as an ever rolling stream . . . There's one thing quite certain in this business: The idea of time as a steady progression from past to future is wrong. I know very well we feel this way about it subjectively. But we're the victims of a confidence trick. (Frederick Hoyle)

The physicist and the psychologist seem doomed to an oscillating argument as to whether the elemental should form the basis of the behavioral, or the behavioral should dictate our view of the elemental. Whichever way this disagreement is resolved it is important to note here that the linkage between the poetic, the behavioral, and the physical is not *always* a comfortable one. As we always must at the end, let us now look at death.

Our Certain Demise as The Basis of Humanity

> And time that gave doth now his gift confound. Shakespeare (Sonnet LX)

The Poetry of the Grim Reaper

> Death is the great reprimand which the will to live, or more especially the egoism which is essential to this, receives through the course of nature; and it may be conceived of as a punishment for our existence. It is the painful loosening of the knot which the act of generation has tied. (Schopenhauer).

Of course, Emily Dickinson (1830-1886) is the poet of death and one of her classic works begins with its title (see Franklin, 1998, p. 479):

> Because I could not stop for Death,
> He kindly stopped for me;
> The carriage held but just ourselves
> And Immortality.

There have been many characteristics that we have claimed to be *the* definitive differentiate between human beings and the rest of the animal kingdom. They represent anodynes to the specter that we humans just might not be as special as we have always vehemently protested. I shall not dwell on the spiritual void that facing this reality engenders. I shall only address the claims of science in this respect. Perhaps, one of the last barriers we claim is that of

language. I have heard apes castigated for being unable to participate in human discourse. I have yet to hear a comparable castigation of human linguists for being unable to participate in anthropoid language. Taking communication, at whatever level of sophistication, as the last barrier, simply will not do.

The remaining behavioral difference is our recognition of the *certainty* of death. I emphasize certainty, since animals might recognize death when they see it, and simple awareness of death is no divider. It is the sure and certain recognition of our own eventual personal demise that sets us, a little, apart. Indeed, this is the fascination and shadow of certain death and its whispered promise of immortality that is so simply, so profoundly, and so elegantly expressed in Dickinson's verse. Parenthetically, it is one of the tragedies of great verse that by frequent repetition they become clichés and so easily if so undeservedly dismissed. Of course, most of us spend much of our time and effort placing the fact of our own undeniable personal demise beyond immediate consciousness. But, it is ever the office of the poet to remind us and Walt Whitman (1819-1892) accomplishes this in 'To Think of Time,' (Library of America, 1993, p. 792) part of which reads:

> To think of time-of all that retrospection,
> To think of today, and the ages continued henceforward.
> Have you guess'd you yourself would not continue?
> Have you dreaded these earth-beetles?
> Have you fear'd the future would be nothing to you?

It is the thought of death that colors much of our later years. In the dilution of life, we now not only face this perennial fear, but also the real fear of a twilight life immediately preceding death. Our culture has much to learn from others on the acceptance of death at one end, and much to fear from our scientific attempts to 'conquer' death at the other.

The Science of Death

> "Neither senescence nor natural death are necessary inevitable consequences of life" as Pearl summed it up; the protozoa are potentially immortal; they reproduce by simple fission, "leaving behind in the process nothing corresponding to a corpse." In many primitive, multicellular animals senescence

> and natural death are absent; they reproduce by fission or budding, again without leaving any dead residue behind. "Natural death is biologically a relatively new thing"; it is the cumulative effects of some, as yet little understood, deficiency in the metabolism of cells in complex organisms - an epiphenomenon due to imperfect integration, and not a basic law of nature. (Koestler, 1978).

There is growing evidence to contend that life emerged, evolved, and exists at 'the edge of chaos' (Kauffman, 1993). Systems that reside in such operational 'spaces' possess many interesting characteristics. In observation of such systems, Kauffman (1993) has noted a linear relationship in ln/ln space, between the size of the failures that occur and the frequency with which those failures occur. This characteristic, it is argued, is an intrinsic property of the complexity of the linked system elements and examples such as ecosystems are examined for evidence of this relationship. One line of evidence comes from the work of Raup (1986) who has examined the extinction events of whole species versus their frequency of extinction in prehistoric epochs. His data are plotted on Figure 4 as the solid squares and show some agreement with the theoretically derived relationship shown as the solid line.

We can view the human body as an interactive complex system also and thus posit that the ln/ln relationship holds for human life as well. This suggests that there are enormous number of perturbing events that occur in the body but these largely fail to propagate beyond some small local effect (e.g., intracellular events). Periodically, however, events do propagate sufficient to cause behaviorally noticeable problems. Finally, an event catastrophic enough to destroy the integrity of the whole body occurs and this is death. We can view human society as a linked system, in the same fashion, as the next higher level expression. In this view, there are few fatalities in the young and progressively greater frequency in older individuals, dictated by the ln/ln relationship.

Various actions act to modify a linear representation, such as the prevention of infant mortality and the medical prolongation of life. These actions artificially change population death rates as the theoretical relationship and deviations from it are shown in Figure 4. As is evident from this and the earlier argument I made, we have bought years of extra life but are now paying the behavioral cost.

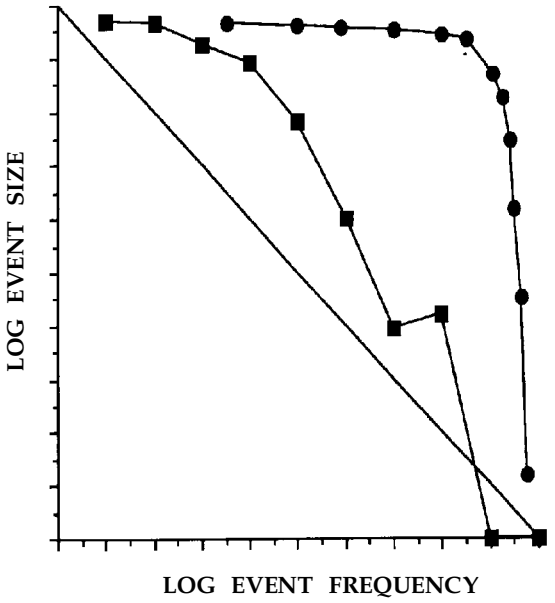

Figure 4: The axes represent the log frequency of events versus the log size of events in complex systems. The linear relationship is a hypothetically perfect one, while the two others represent data. The circles show human cohort morbidity, the squares show extinction events in the Phanerozoic era. Conception after Kauffman, 1993; extinction events data after Raup, 1986; morbidity data imposed here).

Design for Demise

> For the value of that which is truly dear to us cannot be measured by its cost or by its capacity, or by its beauty or by its efficiency. On all these grounds, for sure, the toasted remains of a sixty-year-old teddy bear with a plasticine ear would have scored very lowly indeed. Its true significance lay in something far more profound: something deeply rooted in our own transience; in the acknowledgment of Time and times now lost for ever. And now it was gone. All of it. Not only the present, but the past too. He had vowed to destroy it, and now, strangely, it had destroyed him. (Renwick).

In modern western society, death is a crime. We happily talk of 'expected years of life' and refer to individuals as 'dying young' at ages greatly exceeding average lifespan at the beginning of the last century. While the loss of a child is a true tragedy, we have extended such tragic connotation to all ages

(and see Fraser, 1999, p. 161 for a comparative viewpoint on aging and tragedy). We postpone, we deny, and essentially, are frightened to death - of death. There are few ways to overcome this dominant 'world view' since fear of the unknown is an instinctive human reaction. Our western society largely does not seek to reconcile us with death. Rather, in the same vein as our attempts to 'control' nature, we seek to 'conquer' death. While the search is frequently biochemical in nature, more recent computer science-based approaches have dangled the same tantalizing vision before hopeful believers (Moravec, 1988). Despite such Arcadian vistas, the defeat of death is not imminent. And we must ask whether we would want unlimited years of life if longevity truly does dilute life.

Conclusion

> Every tragedy we can imagine comes down to just one - time slipping by (Arthur Koestler)

What I've tried to convey and confirm in this work is that the evident and central characteristic of aging is time. However, time itself is contingent upon our own personal perceptual experiences and actions we undertake. Thus we are, in part, arbiters of our own aging. The relativity of aging has been the subject of human contemplation for many centuries. Let's hear again from Marcus Aurelius (121-180) who observed that:

> if a man comes to his fortieth year, and has any understanding at all, he has virtually seen - thanks to their similarity - all possible happenings, both past and to come. (Marcus Aurelius)

Given that this would have represented almost *double* the expected life span at that historical era (Figure 1), the comment is, I think, valid. In our times, we might say the same thing if the individual arrived at the comparable age of one-hundred and fifty. However, I would argue here that the ability to experience the whole range of accumulated human knowledge, which is in essence the bounds of collective societal consciousness, has expanded in our times so that one individual would be able to live an order of magnitude greater than an expected lifetime and still not saturate all possible experience. However, in such circumstances we would need to take Campbell's

and Kingsley's admonitions about the demise of our friends and companions most seriously. Despite the potentiality of almost endless 'new' experience, we would have to question *who* we would experience it with since endless novelty without the familiarity of companionship is as daunting as endless repetition.

I want to affirm then that the validity of poetic observation is as relevant as scientific theory and sometimes more so. Each represent ways in which to order observation. Some poetic statements are pure description, but there are also descriptive scientific theories. As much as anything, poetic observations address Aristotle's 'final' cause and propose response to the question 'why.' Our age has directed science to 'efficient' cause and seeks to answer 'how' rather than 'why.' I must admit that as aging begins its personal assault, I am more and more concerned with the 'why' as the 'how' pales into comparable insignificance. At many levels, the physical, the molecular, the physiological, science has its sway. However, at the quintessential human level that of individual consciousness, the poetic can protest its importance, at least to an equivalent value. Written in an age more certain of spiritual omnipotence than our own, let us conclude with an individual doubted for his spirituality, Sir Walter Raleigh (1552-1618) (see Ricks, 1999, p. 56).:

> Even such is Time, which takes in trust
> Our youth, and joys, and all we have;
> And pays us but with age and dust,
> Which, in the dark and silent grave,
> When we have wandered all our ways,
> Shuts up the story of our days:
> And from which earth and grave and dust
> The Lord shall raise me up I trust.

Perhaps she may.

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