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Phenomenological Space-Time: Toward an Experiential Relativity

Abstract. *Subjects observing differently scaled environments undergo systematic shifts in the experience of time. The experience of temporal duration is compressed relative to the clock in the same proportion as scale-model environments being observed are compressed relative to the full-sized environment. This research suggests that spatial scale may be a principal mediator in the experience of time.*

The experience of time and temporal duration is central to mood, feeling, and emotional states (*1*); is often symptomatic of a range of emotional pathologies (*2*) and learning disorders (*3*); and is related to information processing (*4*). Despite numerous studies dealing with temporal experience (*5*), a coherent theory consistently integrating major aspects of previous research findings has not been developed (*6*).

This research suggests that spatial scale—the size of an environment relative to the size of an observer—is a principal mediator in the experience of time and temporal duration; and that for large samples the relationship between spatial scale and temporal experience is subject to precise theoretical formulation.

Spatial scale as defined here is based on the linear dimension, not volume. A wall 12 m long represented by a model in which the wall is 1 m long yields a linear scale of 1/12, while the volumetric reduction is 1/1728 ($1/12^3$).

In experiment 1, adult subjects (*7*) observed different scale-model environments 1/6, 1/12, and 1/24 of full size. Scale-model environments representing small lounges were constructed with cardboard partitions and chipboard furniture as well as scale figures. Subjects were familiarized with the model environments, asked to move the scale figures through them, to imagine themselves the scale figure, and to identify activities appropriate for the space. They were then instructed to imagine themselves the scale figure in the space, to engage in one of the activities previously identified, and to inform the investigator when they subjectively felt (not thought) the scale figure had been engaged in the activity in the scale-model environment for 30 minutes (*8*).

The sample exposed to the 1/24 scale environment was also exposed to the 1/12 environment in order to derive a cross-checking index for scale effects on the experience of temporal duration. Presentation in this sample was counterbalanced. Data consisted of elapsed stopwatch times (*T*) associated with the experiential duration of 30 minutes (*E*) (Table 1).

In order to minimize potential investigator bias, the data for the 1/12 sample were collected in subsamples by 16 different investigators, and the data for the 1/24 sample were collected in subsamples by 13 investigators. The range of compression ratios (CR = *T/E*) across subsamples (1/7.3 to 1/19.5 for the 1/12 model and 1/12.3 to 1/23.2 for the 1/24 model) makes unlikely a systematic, distorting bias attributable to investigator cuing.

Experiment 2 was performed to eliminate potential bias in conjunction with testing in the 1/24 environment. In that environment, large portions of the subject's peripheral visual field were outside the model environment and were stimulated by the surrounding full-sized environment. To eliminate this visual mixing

Table 1. Elapsed time (*T*) associated with experiential duration (*E*) of 30 minutes in differently scaled environments. The compression ratio (CR) is *T/E*. S.E.M., standard error of the mean.

Condition	Model scale	*N*	Elapsed time (min) ($\bar{X}$ ± S.E.M.)	Elapsed time (min) Range	CR*
			Experiment 1 (unmasked)		
Single exposure	1/6	20	4.15 ± 0.630	1.73 to 13.83	1/7.23
	1/12	166	2.52 ± 0.170	0.62 to 11.33	1/11.9
Exposure to two scales (same sample)	1/12	124	2.64 ± 0.133	0.35 to 9.75	1/11.36
	1/24		1.57 ± 0.085	0.17 to 4.92	1/19.10
			Experiment 2 (masked)		
Multiple exposure, same scale (independent samples)	1/6	11	1 5.48 ± 0.619	1.0 to 8.15	1/5.47
			2 5.46 ± 0.561	1.28 to 7.37	1/5.49
			3 5.35 ± 0.501	1.55 to 7.42	1/5.60
	1/12	10	1 2.72 ± 0.417	1.35 to 5.47	1/11.03
			2 2.43 ± 0.453	1.33 to 6.17	1/12.34
			3 2.83 ± 0.531	0.68 to 6.87	1/10.60
	1/24	10	1 1.44 ± 0.274	0.42 to 2.78	1/20.83
			2 1.56 ± 0.312	0.37 to 3.72	1/19.23
			3 1.48 ± 0.255	0.45 to 3.05	1/20.27
Exposure to three scales (random order, same sample)	1/6	27	3.85 ± 0.357	0.98 to 8.58	1/7.79
	1/12		2.60 ± 0.204	0.72 to 5.55	1/11.54
	1/24		1.55 ± 0.179	0.25 to 3.45	1/19.35
			Experiment 3 (masked)		
Group F					
Single exposure	1/12	23	2.89 ± 0.434	0.19 to 8.75	1/10.38
Exposure to two scales (same sample)	1/12	9	2.44 ± 0.448	0.48 to 5.75	1/12.30
	1/24		1.46 ± 0.280	0.20 to 3.23	1/20.55
Group A†					
Single exposure	1/12	32	8.20 ± 0.635	3.85 to 18.2	1/3.66
Exposure to two scales (same sample)	1/12	10	7.36 ± 1.167	4.18 to 15.0	1/4.08
	1/24		6.02 ± 1.58	2.78 to 18.75	1/4.98

*Theoretically CR should equal model scale [$E = x(T)$]. †Sample characterized by acoustic interference, internal auditory timing, or both.

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Table 2. Cross-checking index values (1/12 $T \div$ 1/24 T; dependent variable) associated with T in the 1/12 model (independent variable) based on linear regression lines. Correlation coefficients relate index values to exposure time to the model environment. N.S., not significant.

Study	N	T in 1/12 model (min)						$\bar{X} \pm$ S.E.M.	r	P
		1	2	2.5	3	4	5			
Exp. 1	124	1.58	1.71	1.77	1.83	1.96	2.09	1.79 ± 0.057	.296	.001
Exp. 2	27	1.80	2.02	2.13	2.24	2.46	2.68	2.16 ± 0.249	.179	N.S.
Exp. 3										
Group F	9	1.74	1.75	1.75	1.76	1.76	1.77	1.75 ± 0.208	.013	N.S.
Group A*	10	1.80	1.74	1.72	1.68	1.62	1.57	1.43 ± 0.096	−.701	.05

*Sample characterized by acoustic interference, internal auditory timing, or both.

of spatial scale, a mask was designed to block visual contact with the full-sized environment. Data were collected under two conditions. Independent samples for each scale were exposed to the same model three times to test for practice effects. Another sample was exposed to all three scale models with the order of presentation randomized. Results (Table 1) appear in essential agreement with those of experiment 1.

Experiment 3, an additional replication, also permits an assessment of scale mixing due to acoustic interference and auditory cuing. Since these experiments were conducted in a space subject to distractions (such as occasional typing, phone conversations, and people coming and going), subjects were interviewed after the end of the experiment to determine potential effects of auditory interference. Interviews revealed several timing strategies based on full-sized experiences with the full-sized world—the reenactment of previous, specific conversations of specific music albums with which subjects were familiar. In the first example, subjects indicated they had "heard" each word in the conversation imagined. Subjects using internal auditory cuing for timing themselves often revealed they felt the experiments were designed to test their accuracy of temporal estimation. On the basis of the interview, subjects were classified into two groups. Group A included those who felt they were being tested and those reporting acoustic distractions in the experimental environment. Group F consisted of those who based their sense of timing on their feelings while viewing the model environment. Acoustic interference and auditory cuing made a substantial difference (Table 1).

That the CR's are a function of spatial scale becomes apparent when the cross-checking index in the three experiments is considered. The index is based on the premise that if spatial scale mediates temporal experience, T for the 1/12 scale should be twice that of the 1/24 scale, regardless of how "fast" or "slow" a given individual might be. If, for example, a subject experiences 30 minutes in a 1/12 scale in 5 minutes of elapsed time, his elapsed time for the same experience in a 1/24 model should be 2.5 minutes. Linear regression analyses treating T in the 1/12 model as the independent variable and the cross-checking index as the dependent variable (1/12 $T \div$ 1/24 T) yield the results shown in Table 2. With the exception of group A in experiment 3, results are consistent, indicating a slight increase in the index ratio between scales with increased exposure time to the model environment (*9*). The negative relationship between 1/12 T and the scale index ratio for group A suggests that the presence of acoustic interference from the experimental environment, a feeling of being tested (with reliance upon auditory timing strategies), or both, reduce the effect of reduced spatial scale on temporal experience and do so more effectively the longer the interference or timing strategy is used.

The findings suggest a formulation relating the experience of temporal duration to spatial scale for large samples of subjects who base their experience of time on how they feel and are not distracted by interference from the full-sized environment or burdened by the suspicion of being tested. This relationship can be stated as $E = x(T)$, where x is the reciprocal of the scale of the environment being observed. Thus, in a 1/12 scale environment, 5 minutes of T should result in 60 minutes of E. It should be equally obvious, however, that spatial scale is relative to the size of the observer. In the same environment, a giant should be characterized by $E > T$ (scale < 1), whereas a child would exhibit $E < T$ (scale > 1). This leads to the question of how a normal adult would fare in a normal environment (scale presumably unity).

To find out, 77 observations were made on 15 adults engaged in a variety of normal activities for actual elapsed intervals ranging from 2 minutes to $3\frac{1}{2}$ hours. All temporal cuing—such as clocks, radio commercials, and music—were eliminated. Subjects, who did not know they were being timed, were asked to specify how much time they felt had passed since a prior behavioral event they were aware of. Data were analyzed as before to yield spatial scale (T/E). Results indicate a mean CR of 1/1.02 ± 0.017. The regression equation showed an expected $E = 30.36$ minutes when $T = 30$ ($r = .995$, $P < .001$). The value of E increased its deviation from T as T decreased. A replication sample including 15 observations of five subjects was conducted with T ranging from 15 minutes to $1\frac{1}{2}$ hours. These data result in a mean scale of 1/0.962 ± 0.082. Linear regression analysis results in $r = .904$ ($P < .05$), and an expected E of 35 minutes when $T = 30$. Again, the deviation of E from T increased as elapsed duration decreased. Adults in the normal adult world seem to be characterized by $E \approx T$, and the spatial scale is 1/1. The temporal compression associated with spatial compression seems to constitute a genuine shift in temporal experience.

These studies implicate spatial scale as a mediator in the experience of temporal duration and further suggest that, for large samples, the relationship between the two can be ideally, and precisely, specified as $E = x(T)$.

Spatial scale has not previously been thought to play a significant role in temporal experience. Such a relationship suggests an experiential space-time relativity in which the experience of space and time are relative to one another, manifestations of the same thing. The existence of an experiential relativity would have a serious impact on a variety of conceptual domains and could provide a coherent theoretical framework for integrating data from diverse sources. If light and dark, for example, are considered scale modifiers—light, scale-reducing, and dark, scale-magnifying—experiential relativity should relate directly to Aschoff's rule and the results of free-running experiments on diurnal animals (*10*). Relationships between experiential relativity and other fields of inquiry currently being investigated include neurological functioning, maturational development, central nervous system sensitivity, hyperkinesis, and specific growth rates in size-graded fish populations (*11*).

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7. Subjects were students at the University of Tennessee who volunteered to participate; they were not enrolled in a design curriculum.
8. Typical activities listed by subjects included waiting for someone, relaxing, and a casual conversation. The only restriction placed on the activity simulated was that the subject not place hands or arms in the model during the experiment, which would have constituted a kinesthetic mixing of scales. Subjects were comfortably seated and viewed the scale figure throughout the experiment. It is important to inform subjects they are not being tested with respect to their accuracy of temporal estimation.
9. The cross-checking index ratio derived between 1/6 and 1/12 and between 1/6 and 1/24 scales in experiment 2 are 1.67 ± 0.145 and 3.15 ± 0.353, respectively ($N = 27$). Correlations based on linear regressions between 1/6 and 1/12 and between 1/6 and 1/24 scales are .588 ($P < .01$) and .307 (not significant), respectively (as in Table 2, the larger scale T's are the independent variables and the cross-checking index ratios the dependent variables).
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Soil-Water Equilibria for Nonionic Organic Compounds

Chiou *et al.* (*1*) suggest that solubility in the soil organic matter, rather than physical adsorption, is the appropriate mechanism to explain the soil-water distribution behavior they observed. They eliminated adsorption on the basis of (i) the linearity of isotherms, (ii) heat effects, and (iii) their correlation of distribution coefficients. However, an alternative mechanism involving adsorption may be more appropriate.

The linearity of all the species over the entire composition range is not convincingly established, nor do Chiou *et al.* present an argument, either empirical or theoretical, that prohibits linear isotherms for adsorption. Their discussion of heat effects is apparently based on the assumption that the enthalpy change accompanying adsorption from solution can be determined from the temperature dependence of isotherms, as is possible for the adsorption of pure gases. In the case of pure gases, the state of the adsorbed phase is determined only by the adsorbent loading and the temperature and thermodynamic analysis leads to a Clapeyron-type equation involving the heat of adsorption. When more than one component is adsorbed, however, an additional composition variable is required to determine the state of the adsorbed phase, and the expression involving the heat of adsorption is more complex.

Chiou *et al.* do not show how their proposed mechanism would lead to their correlation of distribution coefficients, or how such a correlation would preclude other mechanisms such as adsorption. Further, a solubility mechanism apparently cannot explain the results of Yaron and Saltzman (*2*), who found that parathion sorption from hexane solution decreased as the water content of soil increased. If parathion were merely dissolving in the soil organic matter, the existence of small quantities of water, which should be immiscible with the oily constituents of the organic matter, would not affect the distribution. Yaron and Saltzman's explanation in terms of competition between water and parathion for adsorption sites seems more plausible; Spencer *et al.* (*3*) reported similar results for lindane and dieldrin.

A simple adsorption model suggests the distribution coefficient correlation found by Chiou *et al.* Manes and Hofer (*4*) adapted Polanyi's theory of adsorption from solution and express the adsorption potential of a solute, ε_s, as

$$\varepsilon_s = RT \,\ell n \frac{C_s}{C_e} + \frac{\varepsilon_\ell V_s}{V_\ell} \quad (1)$$

where C_s and C_e are saturation and adsorption equilibrium concentrations, V_s and V_ℓ are characteristic volumes of solute and solvent, ε_ℓ is the adsorption potential of the solvent, R is the gas constant, and T is absolute temperature. A characteristic curve for the adsorption of a solute on a given adsorbent is constructed by plotting ε_s as a function of the volume adsorbed, ϕ, with

$$\phi = \mu V_s \quad (2)$$

where μ is the molar solute uptake. Following Dubinin (*5*), characteristic curves of various solutes on the same adsorbent are assumed to have the same shape and can be superimposed with the use of an appropriate scale factor for each solute. The solute characteristic volume is commonly used and is expected to lead to a universal characteristic curve, where the scaled adsorption potential, α

$$\alpha = \frac{\varepsilon_s}{V_s} = \frac{1}{V_s}\left(RT \,\ell n \frac{C_s}{C_e} + \frac{\varepsilon_\ell V_s}{V_\ell}\right) \quad (3)$$

should be identical for each solute at equal values of ϕ. The systems under study span a wide range of composition, but the solute concentration is low, and it is reasonable to assign a constant adsorption potential to the solvent. The scaled adsorption potentials for any two solutes will be equal when

$$\frac{RT}{V_{s_1}} \ell n \left(\frac{C_s}{C_e}\right)_1 = \frac{RT}{V_{s_2}} \ell n \left(\frac{C_s}{C_e}\right)_2 \quad (4)$$

In the region where isotherms are linear, the isotherm equation is

$$\mu = GC_s \left(\frac{C_e}{C_s}\right) \quad (5)$$

where G is the distribution coefficient of Chiou *et al.* The condition of equal ϕ for any two solutes is now

$$V_{s_1} G_1 C_{s_1} \left(\frac{C_e}{C_s}\right)_1 = V_{s_2} G_2 C_{s_2} \left(\frac{C_e}{C_s}\right)_2 \quad (6)$$

Thus, Eqs. 4 and 6 are the conditions of equivalency. If the crude approximation of equal characteristic volumes for all solutes is made (*6*), these equations reduce to

$$G_1 C_{s_1} = G_2 C_{s_2} = K \quad (7)$$

where K is a constant.

Equation 7 predicts that a plot of log G versus log C_s should be linear with slope -1. Although the slope of Chiou *et al.*'s correlation is -0.557, the model at least predicts the functionality. Thus, an adsorption mechanism offers a possible explanation for the results of Yaron and Saltzman and of Spencer *et al.* and suggests the correlation found by Chiou *et al.*; the solubility mechanism appears unable to do either.

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