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Temporal tolerance circumscribed

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Chen's topological theory of perceptual organization includes the idea that equivalences in spatial organization and the organization of subjective experiences of time may be derived by means of common expression in terms of topological tolerance spaces. A critique is offered of some foundational concepts related to Chen's suggested organization of subjective time, culminating in the proposal that the organization of time may be best considered with reference to some medium or organization, in this instance the dynamic patterning of nervous system activity. Direct equivalences are then identified between dynamic nervous system activity correlated with spatial and temporal organization. These nevertheless raise the question of whether we need to consider organization of subjective temporal experiences in order to evaluate the idea that variations in process timing is of itself a common mode of expression for spatial and temporal organization.

Event timing and the relative latency of an associated perceptual response is never far from the idea that perceptual priority is allocated to stimuli according to the extent of topological invariance across transformations: It is of course central to Chen's topological approach to perceptual organization in the sense that it is paradigmatic; one cannot infer variations in processing precedence according to topological variance/invariance without manipulations in the timing of stimulus events. But is "psychological time" in a more general sense of any theoretical relevance to Chen's theory of perceptual organization in space?

Chen points out that variability in subjective time relative to the actual timing of a physical event results in the formation of discrete temporal ranges over which the event is perceived or estimated to occur. Range formation applies to the experience of (apparent) simultaneity, temporal order, and/or the *psychological present*: Chen argues that equivalences between the organization of subjective time and the organization of perceptual space may be drawn by common reference to topologically definable tolerance spaces. A tolerance space is a description of the range over which detailed variation in a given stimulus is ignored. The degree of tolerance in space is in principle describable by some function that describes a set of items according to some spatially extended (but nonetheless definable) organization in space. In a similar fashion, a "temporal tolerance space" might be assumed to be some function of the

range of variability in estimated time relative to the actual timing of an event. What's more, equivalence between spatial and temporal tolerance spaces implies psychological time to be possessed of *Prägnanz* in the same basic sense as certain classes of organization in space may possess it.

Before general consideration of the notion and implications of equivalence between temporal and spatial organization it seems necessary to take a particular "position" regarding analogies between spatial and temporal organization and thereafter to identify and resolve two problematic aspects of Chen's suggested organization in time. With respects to taking a position on the possibility for space-time analogies it should be noted that the general analogy is suggestive at first sight, but time is different from space. It is one-dimensional (i.e., it is topologically poor), it is oriented in the time-flow direction and can obviously not easily serve for simultaneous representation of series of nonsimultaneous events. Besides this (and as is repeated later as a major theme of this commentary), the indications are that relations between physical time and phenomenological time are far from consistent. In fact they may be inconsistent to such an extent that it may be difficult to do more than intuit a generalizable structure in phenomenological time and then perhaps better to consider those nontemporal factors to which any pattern of inconsistency ultimately refers. Consequently, it will be argued that any position on the structural relations between (the representation of) space and time must necessarily adopt a flexible outlook, and it is only from a position of flexibility that there exists any substantive basis for further consideration of the notion of (or put another way what actually is) "temporal structure" and how this structure might enter into the topological calculus.

Nevertheless by assuming temporal structure we then encounter our first problems of definition, and these problems relate specifically to the validity of the idea, advanced by Chen (and formerly by Pöppel, 1985, 1997) that events in time are related hierarchically. The concept of a hierarchy entails reference to a system of elements arranged (i.e., related) into graded (i.e., ranked) order. Moreover, it presupposes grading to be defined by some relational, perhaps inherent measure. [As an aside, I think it is probably true to say that the hierarchical representation of relations between tolerance spaces (and what Chen has in mind by reference to the idea of a hierarchy) may be best conceptualized in terms of a "dominance hierarchy" in which, for example, the relations between three tolerance spaces (X, ξ_1) ; (X, ξ_2) ; (X, ξ_3) may be best represented as $(\xi_1 < \xi_2) < \xi_3$. This may not be quite the same idea as put forward by Pöppel, who certainly implies that all temporal experiences are in some way graded relative to one another, but does not seem to define the precise way in which temporal experiences come to constitute their hierarchy.]

However, defining items in terms of some continuum simply because they describe a range of variation along that continuum does not guarantee that the items form a set. If selecting items for set inclusion solely on the basis of their apparent position along such a continuum the resulting set may lack criterion-

related validity. The set may also lack internal validity, particularly when the items concerned consist of a number of attributes and when these attributes are ignored for the purposes of set inclusion. Problematic validity may cause false gradings to arise. An example of the fallacy of grading or ranking simply based upon some measure of magnitude concerns the U-shaped sensitivity functions derived from metacontrast masking. The existence of nonlinearities of this character would necessitate consideration of the two disjunct periods of good target discrimination performance as of separate orders simply because one period occurs "before" and is of a lesser magnitude, whereas one occurs "after" a period of poor performance and is of a higher magnitude. While it may very well be the case that the underlying processes differ, the problem is one of definition; one might not logically be able to define the period of poor performance as a special case if the performance series is considered in terms of three qualitatively different ranges. The implications are subtle but impact at both a systems and at a metatheoretic level of analysis. In the first instance performance might be considered better in terms of three successive but nonetheless related systems as opposed to a single system with nonlinear characteristic. Consequently, at the metatheoretic level the notion of perception as essentially a linear, feedforward system may be supported simply because nonlinearities can be argued away. It may be precisely this problem that Pöppel (1997) seeks to avoid by introduction of the notion of hierarchical gradings of temporal perception. My point, nonetheless, is that it may be misleading to consider all forms of operation in psychological time in this frame of reference.

The notion of a hierarchy may also be somewhat misleading for another reason: The timing of psychological events such as the patterning of estimates in duration discrimination can be shown to obey a quantal staircase law of successive doublings, appearing as a concomitant of ranges whose expansions relate to physical time as a function of Weber's law (see Kristofferson, 1990). Consequently, one can say that at certain intervals, subjective durations will differ in magnitude but these differences in magnitude, while manifest in time, do not refer intrinsically to differences in some magnitude of elapsed time, but of something else that comes to determine their nonlinear characteristic. It might be the case that in all areas except the study of time itself, relations expressed in terms of some temporal characteristic may experience a fundamental problem of reference with respects to expression in terms of ordinal or indeed nominal units of physical time. A more cautious approach to claims of the existence of a hierarchy of psychological time would be to avoid too much emphasis upon arbitrary subdivision in time and consider "to what it is" we are referring by reference to variations in timing of particular, temporally defined experiences or events.¹

¹ At the very least, if we are to question the applicability of the concept of a "temporal hierarchy", we might do so on the basis of its inherent constructivist implications, which tend to oppose the global perspective taken by Chen with regards to perceptual organization in space.

A similar problem accompanies a second aspect of Chen's position on the possibility for spatiotemporal equivalence, notably a common level of description relating various types of subjective time. Evidence certainly exists to suggest a common level of description for different perceptions of stimuli in time, for example the apparent concomitance of the perception of apparent motion with that of precise temporal order judgement, which breaks down as stimuli, perceived as a single moving point under different temporal conditions come to be judged as two successive points (e.g., Westheimer & McKee, 1977). However, and as alluded during earlier discussion of the notion of a temporal hierarchy, it might be difficult to properly quantify links between the experiential characteristics of temporally defined perceptions (such as the perception of (stimulus) simultaneity and the experience of phenomenal "presence"). In this respect, particular caution must be exercised with respects to subjective time for two reasons: Firstly, a consistent and comparable mapping of subjective to objective time cannot be assumed across all classes of temporal experience and secondly, physical time is not a stimulus in the conventional sense of the word. Consequently, and given well-known, but as yet unexplained variations in subjective relative to objective time, it may be difficult to rely upon physical time as a standard.

As a consequence it may be more useful to remain reliant upon the empirical independent definition of each class of temporal experience and consequently in terms of discrete rather than interrelated ranges of variation. In this way, it seems reasonable to consider different types of temporally defined experience in a similar fashion to different types of organization in space, that is to say, related on a metatheoretic level, perhaps in terms of their Gestalt or *Prägnant* characteristics while at the same time subject to lawful, stimulus related variation. What's more, as my colleague Hans Geissler has observed, "establishing measures of subjective time involves knowledge of the *total perceptual-cognitive structures* concerned (quite in analogy to subjective spatial relations)" (H. Geissler, personal communication, emphasis added). This point also applies incidentally to the definition of tolerances, which can only be adequately defined in relation to the percept as a whole. Given that we can currently only speculate concerning the range of processing variation that brings about subjective experiences of time it seems once again sensible to conclude that relating experiences of psychological time may be premature and may suffer from the same lack of criterion-related validity as the idea that types of experience in time should be organized hierarchically.

The establishment of external validity must come about as a continued function of the sensitive covariation of experience and behaviour with stimulus-related variation, as is the substance of time estimation research and what is coming to be referred to as "process psychophysics". Nevertheless, and as counselled above with respects to the definition of a hierarchy of temporal experience, a common definition for events or experiences nominally or

ordinally related in time might be best addressed by reference to something outside of the temporal domain. Henri Bergson was amongst the first to argue on logical grounds that we should consider our conceptualization of “duration” (i.e., extension in time) to draw reference to our conceptualization of “extension in space”. Put in synopsis, Bergson’s position was that “‘dureé pure’ or ‘pure duration’ is wholly qualitative. It cannot be measured unless symbolically represented in space” (Bergson, 1910, p. 104).

However, even by the turn of the twentieth century Bergson’s position relative to the ontological status of temporal experience was not new. In fact there existed in the theoretical reflections of both Gustav Theodor Fechner (1860) and Karl Ernst von Baer (1864) an empirically operationalizable proposal concerning the psychophysical representation (really the physical representation as psychophysics refers to the distribution of energy in a spatially defined system of references) of subjective duration based upon a near identical conceptualization to that given by Bergson. For von Baer “time” was made up of a series of subjective moments, which are equivalent to the briefest time units in which the world appears stationary. In the theme of von Baer and some 70 years later, Brecher (1932) discriminated human moment to be in the order of $\frac{1}{18}$ of a second because pictures, sounds or taps to the skin can only be discriminated if applied at a tempo slower than this rate. In contrast to the human moment, Brecher observed that four tactile stimulations per second with a rod on the belly of a snail compels it to attempt to crawl upon a nonexistent coherent surface which it perceives as a simultaneity (in spite of the considerable delays between application of the stimulating rod). This indicates that the receptor time of the snail has a tempo of three to four moments per second. Consequently, events in the snail’s world will appear much faster than our own experience of them although it might be conjectured that its own motions would seem no slower to the snail than ours do to us. On these bases, it was reasoned the experience of events in time to be both relative and fundamentally determined by structural factors such as the overall length of life and the complexity of the nervous system. In other words subjective time was considered to be a biological property, in part instantiated in the nervous system.

The implications of this position are twofold: On the one hand the desired common level of description upon which substantive parallels might be drawn between temporal and spatial coding might be lie in common operating characteristics within the nervous system. The visual system, upon which basis the great majority of our understanding of spatial coding is derived is very well researched and methods for deriving measures of visual performance, both physiological and psychophysical, offer a level of precision upon which mathematical models of perceptual organization might be designed and tested. Similarly, the question of whether different aspects of temporal experience prove to be governed by the same laws of process operation might be formulated as a set of empirical questions targeted towards a precise specification of what

Pöppel (1997, and by association of ideas, Chen) refers to in terms of the “neurocognitive mechanisms” or the common neural algorithms subserving temporal perception.

What of these mechanisms and how to develop substantives links between nervous system activity and psychophysical performance? Fechner (1860) proposed “inner psychophysics” to comprise cascades of neuronal oscillations, which might serve either singularly or in cascade to ensure subjective time proceeds in accord with physical time. Echoing this proposal, Pöppel (1997) has suggested temporal perception as reducible to patterns of oscillatory activity, going further to suggest the appearance of oscillatory activity at around 33 Hz as of particular significance. What seems promising for an evaluation of equivalences between spatial and temporal organizations is evidence that presentation of spatial organizations of the sort described by Gestalt psychologists correlate with the synchronization of interneuronal firing rates at firing frequencies in a similar range to those described by Pöppel (i.e., in the 30–60 Hz range; see Gray, 1999 for a discussion on this issue). Nevertheless, reduction of the specification of spatial and temporal organization in terms of process timing raises a number of issues. Not the least of these is a proper understanding of the extent to which we should consider the dynamics of nervous system activity to relate better to the idea of organization as it is understood to imply the “act of organizing”, or, as it is intended to refer to, the “state of organization”. Intuitively, the former definition suits the dynamic character inherent in the idea that “organizations” come about as a function of oscillatory activity in the brain. However, and of importance for the aforementioned consideration, is the extent to which the tendency for oscillations to occur at one or other frequency may be best explained in terms of synergism. In other words, to what extent a given neuronal oscillation should be best considered as some emergent property or indeed some reciprocal of a multiplicity of static and inbuilt physical constraints such as neural conduction latencies, refractory periods the extent of the neuronal substrate engaged in a given information processing task, and so on, and indeed, not forgetting determination as a function of other patterns of oscillatory activity.

Issues such as these require resolution before it can be properly decided that temporal and spatial organizations can be considered comparable at the level of nervous system activity. What then of the earlier posed question of the theoretical relevance of psychological time to Chen’s theory of perceptual organization in space? Consistent with the ideas of Pöppel to whom Chen refers, our journey from psychological time has lead to consideration of psychological time as most usefully expressed as patterns in process timing. In this respect, our reduction of subjective time bears striking similarity to a similar reduction of spatial organization. Both can be described in terms of process states that express themselves in oscillatory activity at particular (and closely matching) frequencies. On this basis, and irrespective to the commonality of the neuronal algorithm concerned, we are forced to ask whether or not variations in spatial

organization evaluated relative to covariations (and critically the variability) in associated patterns of process timing would not be, of itself, a sufficient measure of the relations between spatial and temporal organization? Perhaps it is upon this basis that tolerance spaces might be directly computable and quantitative equivalences between temporal and spatial organizations revealed.

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