REPRESENTATION AND PROCESS IN DEFINING HOLISM VS PARTISM: CONTRIBUTIONS FROM GENERAL RECOGNITION THEORY AND STOCHASTIC COGNITIVE PROCESS THEORY

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ABSTRACT

Our target in this brief paper is the issue of holism vs. partism (to coin a term) considered from the points of view of representation, usually thought of as static and either consisting of a feature list or engaging properties of geometry, and process by which we infer properties like dynamism and mechanism. We approach these topics later from the perspectives of general recognition theory (GRT, Ashby & Townsend, 1986) and stochastic cognitive processing theory (e.g., Townsend & Nozawa, 1995). Ultimately, we believe that dynamics, involving how the original percept develops as well as subsequent, and perhaps more cognitive or motor processes operate, must become an integral part of what representation means (e.g., O'Toole, Wenger, & Townsend, 2001; Spencer-Smith et al., 2001).

The notion of holism is itself challenging and its definition continues to evolve through discussion and experimental manipulations. A closely related concept is Garner's *integrality*. Each is in turn related to a 'good form', configurality, or Gestalt, all intimating a unity that goes beyond any mere description of its parts. We shall use the relatively unencumbered name of *Whole* to refer to the complete unity of a thing. One aspect of Whole is that all aspects should be present. As we see below, "all" may be finite or infinite in nature. The opposite of Whole should entail some listing of parts that are in some sense independent. A substantial impediment arises because "independence" has meant a myriad of things to many investigators. We shall relate our view based on our mathematical theories below. We note in passing that an even more opposite notion to a Whole would be an object with parts that are actually antagonistic to one another. It has been thought for decades that the famous Stroop effect, with literally hundreds of studies to its credit (Stroop, 1935) incorporated mutually inhibitory dimensions, that were highly automatic. However, it now appears that the effect appears only with differential salience of the dimensions, or the existence of certain correlations in the dimensions across stimulus presentations (Algom, Dekel & Pansky, 1996). Anyhow, eventually, objects with antagonistic features or dimensions should be brought into the theoretical fold that encompasses Wholes and Part-sets.

All parties who have dealt with the topic of holism have tended to give it their own flavor either through theoretical definition (somewhat rare), operational-experimental definition (more common–see Appendix) or both (occasionally). One other important avenue is to study the structure of good vs. not-so-good vs. bad Gestalts. This is an important question but we are more concerned here, in our ventures with the general aspects of representation.

Obviously, none of the aspects of a Whole mean anything outside of the perceiver. We begin with *representation* inside the perceiver. We think it is important to conceive of the input to any perceptual system, including also subsystems higher in the hierarchy of cognition, as mathematical objects. In the most general sense, these engage set theory, since even nominally defined objects can fit this provision. However, more quantitatively defined objects range from vectors such as area and shape = <A, S> where A= LxW and S = L/W, L=length and W=width, to geometric or topologically defined objects including even the most arcane chaotic (e.g., fractal) sets. Nevertheless, we believe that most signals entering the human sensorium require more sophisticated representations than even finite dimensional vector spaces. That is, many aspects of interest can and should be depicted as topological manifolds, that is, sets of points which can locally (e.g., a neighborhood around a designated point) be mapped in a nice one-to-one and smooth fashion to a Euclidean space (e.g., Townsend & Thomas, 1993; Townsend, Solomon & Spencer-Smith, 2001; Townsend & Spencer-Smith, in press). An important special case is that where the set of potential signals consists of functions from a function space. Interestingly, it is usually overlooked (or forgotten) by psychologists that the background of signal detection theory is based on function spaces.

An ideal Whole would be a manifold in and of itself. Note that this idea can be considered a special extreme case of “all aspects of the figure being present”, since the number of dimensions is infinite. For instance, we have put forth the idea that a perceived face is representable by a geometrical surface, a special kind of manifold (Townsend, Solomon & Spencer-Smith, 2001). What could the space containing such complicated objects be like? This depends intimately of course, on perception. In a strict template kind of space, it might be there is either total congruence (i.e., a distance of 0) vs. incongruence implying a common (among distinct objects) and probably large distance. The so-called trivial metric satisfies this case where $d(x,y) = 1$ (say) if $x \neq y$ and $d(x,y)=0$ if $x=y$. However, it is shown (and already known in mathematics, but not readily accessible for the non-mathematician) in the above paper, that general Riemannian metrics can (with fairly weak conditions) be employed in infinite dimensional spaces of manifolds. Thus, we do not have to relinquish the possibility of interesting metrics just because we move away from the usual finite orthogonal coordinate systems and associated vector axioms. It remains to be seen whether people truly use any kind of metric. Although multidimensional scaling is supportive of this idea, the usual routines do not force strong tests of metric assumptions. Some of Goldstone’s recent results suggest caution in claiming any kind of universal, or even invariant, metric (Goldstone, Medin & Halberstadt, 1997). Still, at least the presence of certain kinds of context effects are prime meat for Riemannian metrics, a fact well-utilized by Albert Einstein.

A Part-set is more difficult to settle in this milieu. Here, one moves down to the maximal “size” parts that are seen as Wholes by the perceiver. Nevertheless, we could hazard that, at least in visual objects, exist as ‘little’ more or less distinct manifolds. This concept simply generalizes the properties of Biederman’s geons (Biederman, 1997). Anyhow, these parts may possess, on the stimulus side, relational properties such as spatial organization, but these, by definition, are not available for employment by the processing mechanisms. Hence, they may have their own geometric or other structure, but they are like independent monads as far as the perceiver goes.

Thus we come by necessity to the distinction of analyzable vs. unanalyzable, *relative to the observer!* In some ways this is the prime differentiator between holistic objects and ones made up of parts that are independent in some sense. However, we believe that these notions unadorned with more precision are inadequate in and of themselves (See Appendix for discussion of operational vs. theoretically based definitions.).

What kind of resistance to analysis should a manifold-defined object exhibit with regard to its parts or dimensions? Suppose that we take as axes of our space, the dimensions of the object (e.g., wavelength and complexity for a color) or, say, evidence for a feature (e.g., a diagonal line) in a figure. Then the structure of general recognition theory (GRT) indicates several ways in which separability might manifest itself: 1. A decision regarding one feature or dimension is the same whatever the decision about another feature or dimension– *decisional separability* (DS). 2. Invariance of a perceptual dimension (feature, etc.) across stimulus levels of other dimensions- *perceptual separability* (PS) 3. Stochastic independence of pertinent perceptual dimensions- *perceptual independence* (PI).

Within GRT then, we hypothesize that a strong form of holism or integrality, should at least make provisions about (2) and (3). We hypothesize that the dimensions in a perfect Whole should be perfectly and positively stochastically dependent (3). But how should being a Whole affect the perception of a feature or dimension when another is altered (2)? In many, but not all cases, we can expect interaction, as when changing the length of the nose can affect the perception of width of mouth in a realistic face. Apparently, however, two features might be perceptually separable, though both are within a Whole. For instance, perception of ear size might be expected to be perceptually separable from eye color, even within an intact face. An ever stronger definition of a Whole might include decisional separability–the inability to make a decision about the level of one feature or dimension irrespective of the decision about another.

We have posited that a fourth aspect of a Whole (Townsend & Thomas, 1993; Wenger & Townsend, 2001) might be super capacity. That is, the perception of a presented Whole may be more accurate (e.g., when presented in noise or tachistoscopically) than when a subset of its parts are presented, particularly if the parts are presented in a scrambled fashion. However, interestingly, if an alphabet is made up of all combinations of features as we have done in the past (a so-called feature-complete, pure identification design; Townsend, Hu and Ashby, 1981; Townsend, Hu and Kadlec, 1988; Ashby & Townsend, 1986), we have found that with larger size alphabets, accuracy (defined in terms of d' on each feature) decreases the more features are in the stimulus (e.g., Townsend, Hu and Evans, 1984), a limited capacity effect and a failure of a statistic to evidence perceptual separability (Kadlec & Townsend, 1992). We believe holism should incorporate super capacity as an axiom.

Is there anything that is lacking in GRT with regard to these questions? For instance, can response time experiments contribute anything to the solution of holism vs. partism? It actually turns out that stochastic independence, while fully definable in processing theories of response times, is difficult to test there, because of contaminating contributions from sub-processes other than those under study. Hence, GRT, featuring patterns of accuracy is optimal from that point of view since independence is open to direct assessment. On the other hand, architecture, for example the parallel vs. serial distinction, is pretty much opaque from the accuracy standpoint (Townsend & Thomas, 1993), but can be assessed within response time experiments (e.g., Townsend & Ashby, 1983).

Furthermore, capacity is also measurable through response times (Townsend & Nozawa, 1995) as well as in GRT as mentioned above. With regard to architecture, we naturally assume that the parts of a Whole should be parallel, but as expressed through GRT above, should also be perfectly correlated (e.g., Townsend & Wenger, 2001 submitted for publication). Also, just as within GRT, capacity should be super, expressed through measurements available through our cognitive stochastic processing theory (Townsend & Nozawa, 1995; Wenger & Townsend, 2001).

Furthermore, with the advent of stochastic GRT (SGRT; Ashby, 1989; Ashby, 2000; Townsend & Wenger, 2001 submitted for publication), we may now include temporal structure and thus bring on board various important issues of architecture and capacity from the time point of view, as well as accuracy/confusion relations. Note that SGRT begins to help bring structure (original static GRT) into the realm of process and dynamics by merging it with stochastic cognitive process theory (e.g., Townsend & Ashby, 1983). One interesting question within these contexts, is whether accuracy and response time measures of capacity, say, always move in concert. The ubiquity of findings across a variety of settings in perception and cognition where errors increase along with response times (suggesting an absence of speed-accuracy trade-off), suggests this latter supposition might be true. More work on this avenue is in progress within SGRT.

Finally, it seems very likely the case (with much evidence in the literature) that nature allows for a graded sequence from fully holistic to fully partistic. It may be false that the platonic end points even exist in nature!

APPENDIX

Operational definitions can be very helpful, especially in the early phases of theoretical/methodological development. However, since they almost by definition, tend to sit outside a coherent theory or model, they can sometimes be invalid or overly restricted. This is the case, for instance, with Garner's redundancy operational definition of integrality. It has been pointed out that redundancy in analyzable, stochastically independent parallel channels (i.e., Non-Wholistic) will exhibit superior performance compared with single target stimuli (e.g., Lockhead, 1966; Ashby & Townsend, 1986). On the other hand, Garner's operational definition involving interference appears perfectly valid. Nevertheless, another potential difficulty with operational definitions is that while two or more may refer to more-or-less the same concept, they might operate at different levels or in distinct subsystems. For instance, we suspect that Garner interference might mostly be involved at a late rather than early stage of processing, for instance, perhaps down at the response selection stage rather than an early perceptual stage. It would be profitable to discuss Garner's notions in terms of those discussed in the text but space does not allow it. Perhaps the strongest criterion would simply be whether anyone could even perceive a dimension within the Whole. If no one can, then the dimensions are truly integral. Of course, in this case, the question becomes kind of trivial and tautological (there are lots of aspects of things in the natural world that we cannot discern). Still, it could be said that hue and saturation come close to satisfying that criterion for integrality, made more interesting since visual artists appear to be able to analyze these dimensions. In the final analysis, we suggest that operational definitions should optimally be absorbed within a global theoretical/methodological framework at the earliest opportunity. They then become part of a unified arsenal of techniques to probe information processing and retention structures.

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