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On taxonomy construction by recursive generative logic

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Abstract

A potentially novel formal, systematic approach for theory-informed taxonomy construction is presented based on maximizing qualitative differences among defined taxa through generative logic. A recursive-dialectic taxonomy is a special form of classification constructed through recursive application of a logical function based on narrowly defined formal operations of absolute antithesis and absolute synthesis. Recursive-dialectic taxonomies have features that may offer advantages from both theoretical and applied perspectives across many different disciplines. The generative approach ensures that taxa are maximally conceptually distinct within the underlying theoretical framework from which the taxonomy is constructed. Such a taxonomy is also quantitatively well-defined, as it maps straightforwardly into a *k*-simplex closed property space in which geometrically defined taxonomic differentiae and typological dimensions are derived from and conceptually linked directly to the underlying theoretical basis of the taxonomy. The resulting closed property space is an Aitchison space that can be treated as compositional data for purposes of statistical analysis in empirical research based on the taxonomy. The relationship of the taxonomic method to Belnap–Dunn logic of first-degree entailment is noted. An example of application of the method to construction of a taxonomy of human sociocultural systems based on social coordination theory is illustrated.

Keywords Taxonomy · Typology · Dialectic · Property space · Coordination theory · Paradigmatic framework

Facts are the world's data. Theories are structures of ideas that explain and interpret facts. — Stephen Jay Gould.

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1 Introduction

Classification and theory construction have long gone hand in hand. From the ancient formulations of the four "elements" of earth, air, fire, and water, through the advent of the periodic table of the chemical elements to the standard model of modern particle physics, taxonomy and typology have informed and reflected the development of our theories of the real world. Alchemy gave way to chemistry and experimental science eventually led the way to Mendeleev's taxonomy of the chemical elements based on valence and atomic weight, which, despite its limitations and incomplete theoretical assumptions, predicted the existence and nature of missing elements, including germanium, gallium and scandium, and ultimately contributed to refining the theory of chemical elements and atomic structure.

Outside of biology, where modern genetic cladistics has challenged and changed traditional taxonomy based on morphology and observable traits, much current taxonomy is more or less pure classification, focused more on description and on simplification and standardization of discourse than on explanation and theory building. In many fields of study, modern taxonomic efforts have long been largely powered by computational methods applied to large data sets using a variety of partitioning and clustering techniques based on computation-intensive methods (Bailey 1994), now including advance statistical techniques, artificial intelligence, neural networks, and adversarial learning. Computational approaches have more recently been used to create taxonomies of phenomena as diverse as smartphone apps (Nickerson et al. 2009), drug indications (Fang et al. 2024), and user intentions (Shah et al. 2025). Such taxonomies may be of substantial heuristic and practical value in organizing data within specific areas of interest, but they are often largely divorced from and devoid of theory. They can facilitate dialogue about phenomena and comparisons among research findings, but all too often these computed taxonomies offer little in the way of explanation of the underlying phenomena.

The purpose of this paper is to describe an approach to taxonomy construction quite distinct from such computationally-based classification methods. The author is neither a taxonomist nor a mathematician but a systems theorist (Whitchurch and Constantine 1993), and the approach described here emerged over the extended evolution of a rigorous systems-theoretic taxonomy of human socio-cultural systems (Constantine 1983, 1986, 1988, 1993, 2025a, b). The approach, however, may have broader potential in many areas of theory-oriented taxonomy and typology, particularly where the overall objective is the pursuit of what Einstein (1934, p. 165) described as "the supreme goal of all theory," namely, "to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience." It invites application for refinement and extension in those many contexts in which theory and/or empirical evidence has established a model contrasting two opposite types or classes. Such models are, of course, ubiquitous, especially in the social and behavioral sciences.

1.1 Taxonomy as theory

Classical approaches to taxonomy in the natural sciences, such as in biology, chemistry, and physics, even when largely descriptive and empirical, have ultimately been oriented toward explanation, to theory construction, that is, to building structures of ideas that explain and interpret data, to paraphrase Stephen Jay Gould (1981). The periodic table of the elements is such a structure, often held up as an exemplar of the interplay of taxonomy and theory and still considered among the most "useful classifications of modern science. Its predictive and explanatory power is invaluable" (Seifert 2025). Feger (2001), in writing on classification in the social sciences, also cites Mendeleev's periodic table of the elements as a paragon of taxonomy based on five criteria: (1) theoretical foundation for the classes and their structure, (2) objectivity of assignment to classes, (3) completeness in coverage, (4) simplicity in terms of classification criteria, and (5) prediction of new variables, objects, and relationships (Feger 2001, pp. 1967–8). This last criterion particularly distinguishes purely descriptive taxonomy from taxonomy as theory, in that prediction enables discovery of taxa and their interrelationships beyond those that are computationally identified from statistical clusters within a given data set or otherwise observed in available samples. Prediction allows for the empirical testing and validation of the taxonomy itself as a model of the underlying phenomena. Discovery of missing taxa or verification of predicted properties is evidence in support of the theoretical model; failure to find taxa or properties as predicted puts the theory in question.

Despite its long established role in science, classification in the broadest sense and taxonomy and typology in particular are often considered as something quite apart from theory (e.g., Marradi 1990) or as mere intermediates on the way toward theory (e.g., Doty and Glick 1994). However, in the natural sciences, theory and taxonomy can also sometimes be inextricably intermingled, as in the case of the periodic table of the elements.

For another such example of more recent emergence, consider the so-called Standard Model of Particle Physics, a taxonomy often visualized in tabular form (Fig. 1). The Standard Model is a taxonomy that classifies all known elementary particles into fermions and bosons, leptons and quarks, and scalar and gauge bosons. It also constitutes a theory of three of the four fundamental forces of the universe—the electromagnetic force, the weak force, and the strong nuclear force, omitting only gravity—along with their relationships to the fundamental constituents of all matter. This taxonomy predicted and led to the discovery of new particles, including the tau neutrino, the top quark, and the long elusive Higgs boson, often hyped in the press and in the popular mind as the "god particle," the force carrier that is the foundation of mass. The discovery of these particles with their characteristics as predicted validates the taxonomy as a model along with the underlying theory that it models. It is worth noting that prediction and validation of such a taxonomy is made possible by its structure, in this case tabular, that exposes potentially missing categories.

Taxonomies and typologies are typically distinguished from each other on the basis of their method of construction (Smith 2002). Taxonomies are generally regarded as classifications of empirical entities (Bailey 1994, p. 6) and are distinguished from typologies, which originate with theoretical assumptions, usually in the form of one or more defining dimensions or factors (Bailey 1994, p. 4). Typologies of one or two dimensions are ubiquitous in the social and behavioral sciences. One dimensional typologies include such well-known examples as theory X and theory Y in management (McGregor 1960) based on negative or positive assumptions about typical workers, and Gelfand's tight-loose culture model based on the strength of norms (Gelfand 2018). Two dimensional typologies also abound in the social and behavioral sciences, including, for example, Kolb's four learning styles of visual, auditory, reading/writing, and kinesthetic (Kolb 1984) based on dimensions of abstract versus concrete thinking and active vs. reflective observation or Baumrind's four parenting styles of authoritative/democratic, authoritarian, permissive, and neglecting/uninvolved

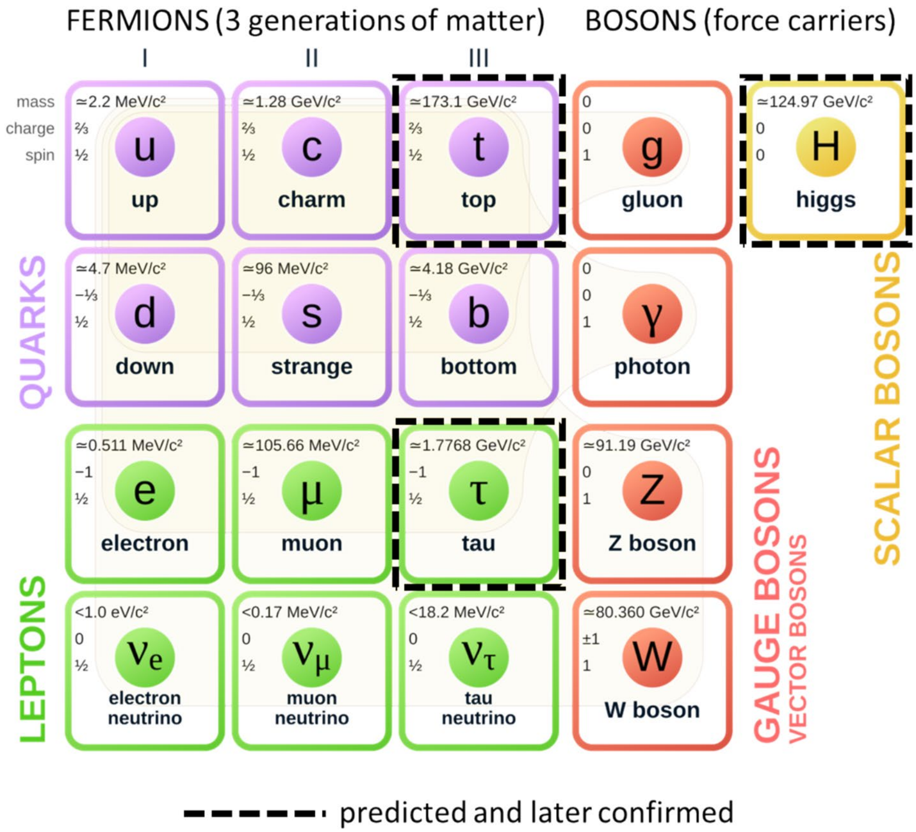

Fig. 1 Standard model of particle physics as example of predictive taxonomy (Public domain, CC 1.0, Wikimedia)

(Baumrind 1971) based on dimensions referred to as parental responsiveness and parental control (but see, Constantine 2025a, pp. 182–184).

In practice, the distinction between taxonomy and typology is not always clear and may even be flagrantly ignored. For example, the widely known Pew Political Typology (Pew Research Center 2021) distinguishes nine political “types” based on political values and beliefs among American citizens. “Typology groups” were constructed through statistical analysis of survey data using clustering techniques, specifically weighted clustering around medoids (Pew Research Center 2021, p. 132). In other words, this political “typology” is actually a taxonomy. That said, the Pew typology is modeled as a spectrum ranging from dark red, “Faith and Flag Conservatives,” through dark blue, “Progressive Left,” implying a possible underlying dimension reflecting the traditional left–right political axis (Pew Research Center 2021, p. 5).

2 Taxonomy through recursive logic

The method for taxonomy construction described here is based on recursive application of a particular form of dialectic logic and leads to taxonomies that are also typologies, that is, that are empirically based classifications anchored in theory with classes that are also definable by theory-based dimensions or factors. In this, the approach forms what might be termed typological taxonomies that integrate the purely conceptual level of analysis and the empirical level of analysis in a third level, a mapping of the two termed the "indicator" level (Bailey 1984). The goal in any case, is to maximize between-class variance and minimize within-class variance (Bailey 1994, p. 1). This means identifying highly coherent classes based on clearly defined concepts that are maximally distinct from each other, both conceptually and analytically, with clearly defined relationships, toward the ultimate objective of explaining and interpreting the phenomena of interest, not merely naming and describing its content (Branch and Rocchi 2015).

2.1 Dialectics

Regarding the dialectic, dialectics, and dialectical logic and reasoning, there is broad consensus that there is little or no consensus on what the dialectic is, what it means, or for what or how it applies. In sociology alone, for example, the dialectic and dialectics have been used with many different meanings and interpretations (Schneider 1971). Even Plato, the putative originator of dialectics, "uses the term dialectic throughout his works to refer to whatever method he happens to be recommending as the vehicle of philosophy" (Meinwald 2025). Arguably the two most widely recognized variants of the dialectic are as a form of argumentation attributed to Plato and Aristotle (Strauss 1987)—what Goldstein (2015, p. 38) refers to as "the bracing dialectic wind stirred by many clashing viewpoints"—and the historical dialectics of Marx and Engles (Avineri 1968).

The dialectic in its many forms and variants has, at least since Fichte (1982 [1794/95]), one near-universal feature, namely the three familiar contrasting concepts referred to as thesis, antithesis, and synthesis. A dialectic series is the result of treating synthesis as another thesis from which its antithesis can in turn be derived. The meanings assigned to antithesis and synthesis vary widely. Antithesis can be taken to mean, among other interpretations, a simple reaction or response to a thesis, a concept or phenomenon in tension with a thesis, a probable or inevitable consequence of or successor to a thesis, or some element in dialogue or exchange with a thesis. In turn, synthesis may mean, among others, a simple mixture or combination of a thesis and antithesis, a compromise or intermediate between thesis and antithesis, a probable or inevitable consequence of or successor to an antithesis, or any form of conclusion or resolution of conflict, contrast, or tension between a thesis and its antithesis. At the extreme, for example, is a use of a "dialectical approach" in classification (Adams and Adams 1991) in which the dialectic simply means an interplay between empirical findings and classification in which classes and their boundaries are revised as new evidence accumulates.

2.2 Recursive dialectic

The term *recursive dialectic* (RD) is used here to refer to a specific restricted form of the dialectic, a conceptual series generated by recursive application in alternation of two logical operations, designated as *absolute antithesis* and *absolute synthesis* and represented herein by the notations |¬| and |**&**|, respectively. Although perhaps not fully formalized, these are here defined and clarified with examples more narrowly than is typical of the broad, highly variable, and often subjective manner in which the terms antithesis and synthesis have been used in much of the literature, as noted above. This level of formality and restriction is considered suited-for-purpose in conceptual taxonomy construction.

Absolute antithesis is the polar opposite, the negation, reversal, or inversion of relevant attributes, features, or characteristics of a thesis, not merely some construct in reaction to, contrasting with, different from, or in tension with a given thesis. Absolute antithesis is contextual, that is, defined within a particular domain of discourse and its semantics. For example, in temporal orientation, the absolute antithesis of "continuity" would be "discontinuity" (or "change"). However, absolute antithesis is not deterministic (single-valued) in all cases. For example, in the domain of human psychology, the absolute antithesis of "dependent" would be "independent," but it can also be argued that the absolute antithesis could be "counter-dependent." This characteristic of the recursive dialectic is not necessarily a defect in that it allows for different models of semantic difference.

Absolute synthesis is an integration of a thesis and its absolute antithesis comprising emergent characteristics, features or attributes that combine or join polar opposites rather than being mere mixtures or intermediates between extremes. Absolute synthesis introduces characteristics that are novel and not found in a thesis or its absolute antithesis, that is, comprising characteristics not represented in the distinction(s) between a thesis and its absolute antithesis as defined within a particular domain of discourse and its semantics. An absolute synthesis of "dependent" and "independent," for example, would be "interdependent," which is both dependent and independent, an integration having its own distinct (emergent) characteristics rather than some compromise or mixture of dependent in itself or independent in itself.

Whereas thesis and absolute antithesis represent "either/or" reasoning with respect to dichotomies or polar opposites, absolute synthesis represents "both/and" reasoning. In this respect, absolute synthesis may be construed as violating *tertium non datum*, at least semantically. If some attribute or quality is true of a thesis, then for the absolute antithesis that attribute will be false and for absolute synthesis that attribute must be *both* true *and* false. As Ball (1979, p.788) notes:

> The capacity of dialectical thought to reveal contradiction, opposition, negation, dilemma and paradox ... is very closely tied to its appreciation of the ambiguities involved in the process of contextual relationships. Modern logic allows us to deal with this sort of problem, and it was the dialectical tradition which led the way.

In classical logic, laws of the excluded middle and non-contradiction prevail, but some contemporary perspectives, such as paraconsistent logics (e.g., Dunn 2019) and dialetheism (Priest 1998) offer alternatives. The formal logic implications and underpinnings of the recursive dialectic will be explored further in the section on analytical structure below.

Absolute antithesis and absolute synthesis ensure that the resulting concepts or constructs are conceptually maximally distinct. This is in marked contrast to the broader and less restricted definitions common to many interpretations of dialectics. If antithesis is merely some development or outcome in reaction to a thesis, for example, then antithesis can be anything. Even in some more precisely defined dialectics, definitions may admit almost any solutions. For example, in dialectical ontology (Musgrove 2019), an antithesis is defined as something with "at least one outcome that has negative valence or negative utility in regards to the very same purpose or function as the thesis" and a synthesis has "at least one different characteristic, such that the entity now lacks a function or consequence that in the exhibited antithesis bears a negative value."

2.3 Recursive-dialectic taxonomy

A recursive-dialectic taxonomy (RDT), $\mathbb{T}_N(D)$, is a formal taxonomy of N taxa, T_1 through T_N, in some domain, D, generated by a recursive dialectic and mapped into a closed property space, a *k*-simplex in *k* dimensions ($k = N-1$) bounded by N vertices corresponding to the identified taxa. A *k*-simplex is the simplest regular convex polytope in *k* dimensions (Aitchison 1981, 1982); for $k=2$, this is an equilateral triangle, for $k=3$, a regular tetrahedron, and for $k=4$, a pentahedroid (also called a 5-cell), the four-dimensional equivalent of a tetrahedron.

Let $|\neg|x$ be a unary operation on x yielding the absolute antithesis of x.
Let x $|\&|$ y be a function of x and y yielding the absolute synthesis of x and y.

(1) $|\neg|\,(|\neg|x) = x$
(2) $x\ |\&|\ y = y\ |\&|\ x$
(3) $x\ |\&|\ x = x$
(4) $x\ |\&|\ \{\} = x$
(5) $x\ |\&|\ (y\ |\&|\ z) \neq (x\ |\&|\ y)\ |\&|\ z$
(6) $|\neg|(x\ |\&|\ y) \neq |\neg|x\ |\&|\ |\neg|y$

Let C be a defined and described construct or concept within domain D derived empirically and/or established by theoretical argument. C comprises a set of attribute values, $\{a_1, \ldots a_j\}$, where each a_i is a specific member of a set of possible values A_j. At least one A_j is definitional for taxa within the domain D, that is, all taxa within domain D must have valid values for such attributes.

Then, $\mathbb{T}_N(D) = \{T_1 \ldots T_N\}$, where:

$T_1 = C$
for $i = 2, 4, \ldots : T_i = |\neg|T_{i-1}$
for $i = 3, 5, \ldots : T_i = (T_{i-1}\ |\&|\ T_{i-2}) = (T_{i-1}\ |\&|\ |\neg|T_{i-1})$

Although potentially open-ended, the series is limited to instances within the domain D, and thus terminates when application of the recursive dialectic generates a term, such as a null case or empty set, not within the domain D based on the defining attribute(s). The choice of C, the starting point of the recursive-dialectic series, is not arbitrary and may determine the number and specific form of the taxa in the taxonomy. Where the starting point is an extant model based on polar opposition, however, the results are the same starting with either pole, since $C\ \mathbf{|\&|}\ |\neg|C = |\neg|C\ \mathbf{|\&|}\ C$ (by (2) above). The choice of C in relation to the underlying theory is explored further in the section on application to a specific taxonomy.

2.4 Analytical structure

The recursive-dialectic logic can be interpreted geometrically, that is in terms of analytical geometry. In this sense, a thesis and its absolute antithesis define a closed property space whose geometry is one dimensional, a line segment demarcated by the polar opposites: TA in Fig. 2a. Within such a classification scheme, any actual instance can be represented as a point along the line segment, an admixture of a thesis and its absolute antithesis. A salient contemporary example of such a taxonomy in the social sciences is Gelfand's tight-loose culture model, which distinguishes tight cultures with many strongly enforced rules, from loose cultures with fewer rules and weaker enforcement (Gelfand 2018). In this model, the taxa are tight and loose cultures, with loose cultures the antithesis of tight cultures in terms of number and strength of rules. Actual cultures may fall anywhere on the line between the extremes. The polar opposites of tight and loose cultures define an empirically bounded subset of a continuum that, in principle, could be thought of as extending from no enforced rules to infinitely many perfectly enforced rules.

Absolute synthesis with its emergent features, properties, or characteristics, necessarily introduces an additional dimension orthogonal to that distinguishing the thesis and absolute antithesis rather than merely an admixture, compromise, or midpoint between thesis and antithesis in the same dimension. Analytically, the introduction of an absolute synthesis defines a closed property space in the form of a regular equilateral triangle, TAS (Fig. 2b). For a unit triangle, any point, P, in this property space can be represented in trilinear coordi-

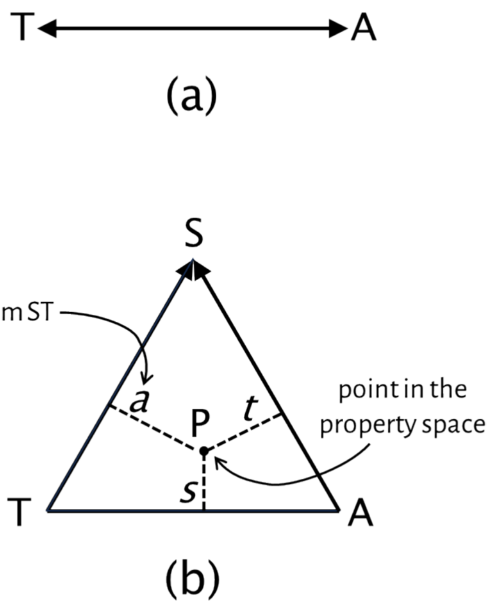

Fig. 2 Analytical geometry of absolute antithesis and absolute synthesis

nates (Mertie 1964), (*t,a,s*), as an admixture of thesis, antithesis, and synthesis summing to 1, that is, the relative proportion of the thesis, antithesis, and synthesis.

Taking a synthesis as a new thesis leads to a (potentially) open-ended series of concepts or constructs. The resultant dialectic series comprises a partially-ordered set defined by logical relationships. It is crucial to understand that this series is synchronic rather than diachronic, that is, it is based on recursive logical dependency rather than constituting a time series implying evolution or temporal succession or causal connection as, for example, in the dialectics of Marx and Engels.

Analytically, the general case of an RDT represents a closed property space, a *k*-simplex of $k = \mathrm{N} - 1$ dimensions bounded by N vertices defined by the N taxa for the taxonomy $\mathbb{T}_{\mathrm{N}}(\mathrm{D})$. For purposes of statistical analysis, this property space can be interpreted as an Aitchison space representing compositional data (Aitchison 1982; Egozcue and Pawlowsky-Glahn 2019), that is, any interior point corresponding to an actual instance is a convex composition defining the relative proportion of each of the taxa in that instance.

Interpretation as a *k*-simplex Aitchison space is not limited to RDTs but can apply to any taxonomy that admits or models admixtures of taxa, including statistically-based taxonomies such as those derived from archetypal analysis (Cutler and Breiman 1994), which directly generates taxa defining the convex hull (boundary of the property space) covering the data set. However, as a means for constructing taxonomies, the recursive dialectic has distinct advantages in defining taxa that are maximally qualitatively/conceptually distinct, since absolute antithesis, the polar opposite of thesis, is as conceptually different as possible, and absolute synthesis necessarily introduces characteristics that are emergent and therefore not characteristic of either a thesis or its absolute antithesis. This is readily apparent in the analytical geometry of Fig. 2, in which the synthesis, S, does not lie within the line TA. Indeed, as the diagram makes self-evident, no point within the property space with a non-zero value of *s* (having some degree of similarity to S) falls within the line TA representing admixtures of T and A.

For N = 2, the property space is a line segment (Fig. 3a) of unit length representing the relative proportion of or similarity to T_1 and its antithesis, T_2. For N = 3, the property space is an equilateral triangle (Fig. 3b) of unit height within which any point corresponding to an actual instance can be represented by trilateral coordinates (Mertie 1964) expressing the relative proportion or similarity to T_1, T_2, and T_3. For N = 4, the property space is a regular tetrahedron (Fig. 3c) of unit height metricized in quadrilinear coordinates (Mertie 1964). The vector normal to a bounding edge or face to an opposite vertex can be interpreted as corresponding to a differentia, d_{i} for taxon T_{i}, that is, a property or properties intrinsic to the taxon at the vertex and distinguishing it from all other taxa. These features can be generalized to higher dimensions but are not easily illustrated graphically. The coordinates of any point within any such property space can be expressed as an n-tuple (d_1, d_2, … d_{N}) that sums to 1. The intersection of these differentiae is located at (1/N, 1/N … 1/N). Taking the differentiae as factors, the correlation between any two is, of course, the cosine of the angle between them and will be, by elementary geometry, $-1/(\mathrm{N}-1)$. Thus the correlation between differentiae is -0.5 for N = 3, -0.33 for N = 4, -0.25 for N = 5, etc. (Constantine 1993). Thus differentiae are clearly not orthogonal factors.

The recursive dialectic as a form of logic can be shown to be related to other multi-valued logics, in particular the Belnap–Dunn logic (Dunn 2010, 2019) of first-degree entailment (FDE), a formal logic with four truth values: T (true), F (false), B (both true and false), and

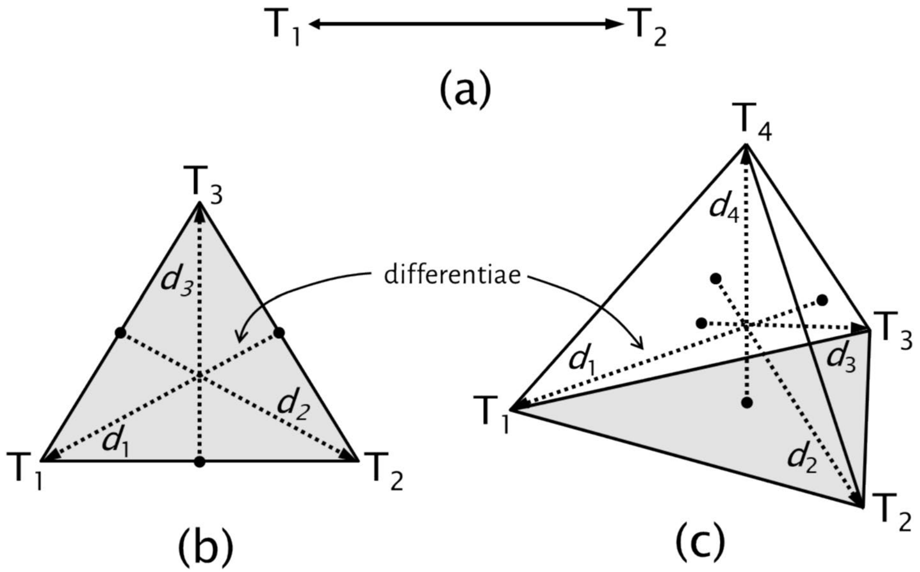

Fig. 3 Analytical geometry of two, three, and four taxa recursive-dialectic taxonomies

N (neither true nor false). This logic corresponds to a recursive dialectic of truth values with C = True, thus $\mathbb{T}_4$(FDE) = {True, False, Both (both True and False), Neither (neither True nor False)}. Dunn (2010) generalized the four-valued FDE logic to include degrees of truth in the form of an "Opinion Tetrahedron" representing degree of belief (T), disbelief (F), conflict (B), and uncertainty (N) as coordinates in a bounded space, visualized in one of his last papers (Dunn 2019, p. 94). This generalization (Fig. 4), is readily seen as structurally and semantically isomorphic to Fig. 3c, above.

However, Recursive Dialectic logic is not identical to Belnap–Dunn logic in that it has a different interpretation of logical negation, as can be seen from the truth table below (Table 1). In Belnap–Dunn, the negation of B is B and the negation of N is N. In Belnap–Dunn, the possible truth values comprise the power set of {T,F}, namely {{T}, {F}, {T,F}, {}}. In other words, Belnap–Dunn logic does not treat B and N as truth values in and of themselves at the same level as T and F. B comprises the set {T,F}, the negation of which is the negation of the members of the set, thus {¬T,¬F} = {F,T}, which is merely B.

The Recursive Dialectic treats B and N as different "kinds" of truth, that is, as truth values per se. Something that is both true and false is a contradiction or paradox, which is seen within this logic as an admissible state or truth value in its own right, in that absolute synthesis introduces emergent features not true of a thesis or its absolute synthesis. Similarly, N, neither true nor false, can mean uncertainty, ambiguity, unknown, or even unknowable, which in the Recursive Dialectic is a state or truth value in itself.

The RD version of truth values thus forms a possible additional paraconsistent 4-valued logic, but the full pursuit of the implications of the connections and differences in logical assumptions to Belnap–Dunn is beyond the scope of this paper. Here the concern is the utility of the Recursive Dialectic as a means to theory construction through taxonomies of real-world phenomena. In this regard, perhaps it bears highlighting that in both modern mathematics and contemporary physics, paradoxes and contradictions abound. A beam of

Fig. 4 Analytical geometry of Belnap–Dunn logic (adapted from Dunn 2019, Fig. 7, p. 94, used with permission)

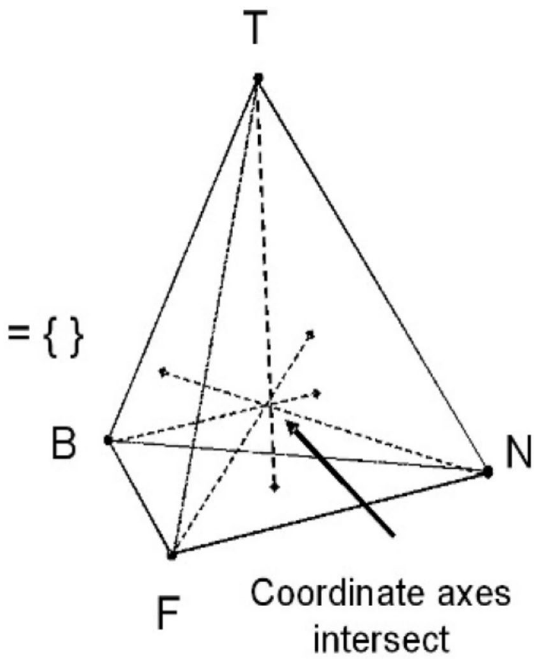

Table 1 Truth table for negation in Belnap–Dunn (BD) and recursive-dialectic (RD) logics

	BD	RD
x	$\neg x$	$\mid\neg\mid x$
T	F	F
F	T	T
B	B	N
N	N	B

light is simultaneously a wave and not a wave; a mathematics that is complete necessarily includes contradictions.

The relationships between simplex coordinates and coordinates in conventional Euclidean real space are well understood (Mertie 1964). In the case of N = 4, one such relationship (Fig. 5) is of particular interest.

The axes x, y, and z, connect the midpoints of opposite edges of the closed property space, defining pair-wise distinguishing aspects of the taxa and are thus intrinsically tied to the underlying theoretical basis of the taxonomy. Note that these dimensions are derived from and based on the taxonomy, in contrast to a typology, wherein the dimensions are first assumed or postulated and types corresponding to the orthants of the property space follow as a consequence.

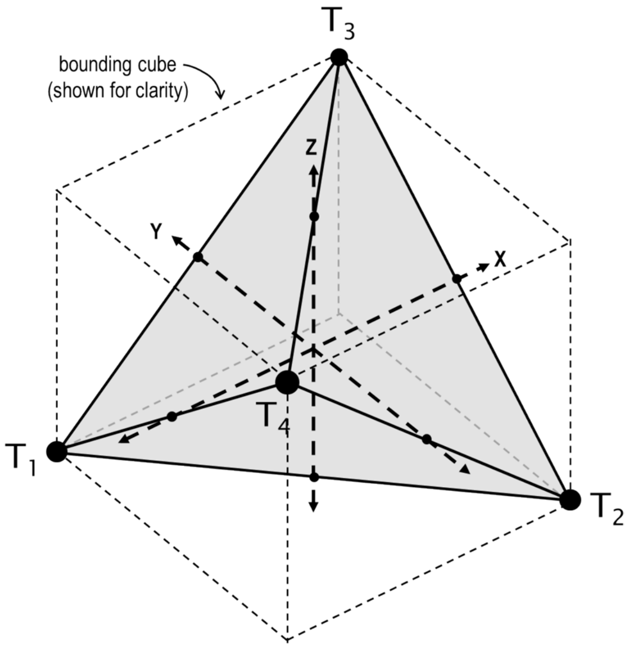

Fig. 5 Orthogonal dimensions defined by edge-to-edge axes in four-taxon taxonomy

3 Application and example

The method of taxonomy construction described above emerged from necessity over the course of the extended development of Social Coordination Theory (Constantine 2025a, b), a formal theoretical framework for understanding how human groups of all kinds, regardless of scale, are able to coordinate and sustain patterned collective behavior, that is, to function as a whole, as a system. At this writing, to the best of the author's knowledge, Social Coordination Theory appears to be the only complete instance of theory construction through application of a formal recursive-dialectic logic. For this reason, it may be instructive to review the content and evolution of this theory.

A human system is defined as any organized assemblage of human actors (participants) exhibiting sustained patterned collective behavior. This broad definition of a human system based solely on observable collective behavior thus includes everything from couples and families, work teams and small business, to nation states and global enterprises. The theory comprises a recursive-dialectic taxonomy of human socio-cultural systems originating in empirical observation (Kantor and Lehr 1975) and resting on the following small set of fundamental principles (Constantine 2025b, pp. 3–4):

1. Patterned collective behavior in human systems requires coordination.
2. There are a limited number of physical mechanisms by which collective behavior can be coordinated, namely negative feedback (deviation-attenuating), positive feedback (deviation-amplifying), and internal programming of actors (shared mental models).

3. Human systems can be understood in terms of process (function, behavior), organization (structure, relationships), and paradigm (guiding model, worldview).
4. There are a limited number of fundamental issues that all human systems must address (Hills 2002; Kluckhohn and Strodtbeck 1961), including, among others, the relative priorities of continuity and change and of the collective and the individual.
5. Process, organization, and paradigm are mutually reinforcing; particular patterns in process favor and are favored by particular forms of organization and particular guiding models.

This last principle, the Congruence Principle, means that a single map, a taxonomy based on the underlying mechanisms of coordination, also covers worldviews as well as organizational or structural patterns. The close interplay of organization, collective behavior, and construction of reality, both individual and collective, has been identified in both family studies (Reiss 1971, 1981) and group dynamics (Kruglanski et al. 2006) based, at least in part, on need for closure in problem solving (Kruglanski and Webster 1996).

3.1 Background

Social Coordination Theory and the Paradigmatic Framework, as the resulting taxonomy has been called (Constantine 1983, 1986, 1988, 1993, 2025a), originally grew out of ground-breaking empirical research on the everyday life of families by Kantor and Lehr (1975). Although Kantor and Lehr did not identify it as such, the research employed what was essentially a grounded-theory ethnographic approach (Glaser and Strauss 1967) in which each family was approached as if it were a new and unique culture to be understood. Intensive and extended close observation and assessment in many areas of everyday family life were employed in building, refining, and validating an emerging theoretical model dynamically over the course of the study. This study identified three different patterns of coordination comprising a taxonomy based on stability, variety, and adaptability as three distinct organizing principles. Each of these organizing principles was seen to be supported by distinct patterns of feedback communication.

Stability-oriented families, called Closed by Kantor and Lehr, were found to be dominated by negative feedback, communication that served to attenuate deviation or departures from a family's established norms of continuity. Variety-oriented families, labeled Random, were dominated by positive feedback loops that served to amplify change and reinforce variety. A third pattern, called Open, was seen to be coordinated by a flexible synthesis of both negative and positive feedback loops that achieved both stability and variety through an emergent commitment to adaptability rather than to either stability or variety per se. Each of these patterns constitutes a paradigm (Constantine 1986), that is, a model of a kind of human system, such as a family, and a corresponding worldview (Koltko-Rivera 2004) or construction of reality (Reiss 1981). These three patterns logically comprise the first three terms of a recursive-dialectic series, as can be seen from examining the first three columns of Table 2.

Columns in this table describe each distinct taxon; rows detail relationships among the taxa with respect to a few selected attributes. The first four rows constitute defining characteristics; the bottom three are derived directly or indirectly from the constructed theory. For example, reading across on the fourth row, we see the priorities are a straightforward

Table 2 Selected attributes of five human system paradigms (extracted and adapted from Constantine 2025a)

	CLOSED (thesis)	RANDOM (antithesis)	OPEN (synthesis)	SYNCHRONOUS (antithesis)	UNIFIED (synthesis)
Orientation	Stability	Variety	Adaptability	Harmony	Comprehension
Coordination	Negative feedback	Positive feedback	Negative and positive feedback	Neither (shared mental models)	Negative and positive feedback and shared mental models
Time priority	Continuity	Change	Continuity and change	Timeless (neither continuity nor change)	All orientations to time
Part/whole priority	Collective over individual	Individual over collective	Individual and collective	Neither individual nor collective; mutual identification	Whole environment; collective, individual, internal, external
Decision-making	Formal, top-down, hierarchical	Informal, bottom-up, independent	Negotiated consensus, collaborative	Unnegotiated, separate, automatic, predefined	Evidence based from verified models
Task roles	fixed, assigned, differentiated	Variable, ad hoc, unassigned, undifferentiated	Rotated, shared, task-centered	Static, predefined	Universal, fully fungible as qualified
Differentia	Hierarchy of authority	Divergence of solution	Convergence by collaboration	Consentience by shared mental models	Reflexivity by self-referential process

rendering of the recursive-dialectic logic applied to the part-whole distinction or collective versus individual interests. In the Closed paradigm, the prioritization of the collective over the individual means such systems value loyalty, conformity, dependence, and self-sacrifice. By contrast, the Random paradigm values individuality, non-conformity, independence, and self-expression. The column labeled SYNCHRONOUS illustrates how recursive-dialectic logic can predict and characterize a new taxon. An important early question relative to the original Kantor and Lehr classification was whether it was complete, theoretically and empirically. Did their grounded theory capture all possible variants or was it limited by either their relatively small sample or their analysis? On the basis of two different strictly theoretical arguments, an additional possible pattern was identified and first described in unpublished presentations (Constantine 1977, 1980), then in peer-reviewed publication (Constantine 1983), and later confirmed and characterized in greater detail (Constantine 1986; Constantine and Israel 1985).

The first argument arose in answer to the question of whether there was any other mechanism of coordination from which patterned collective behavior could arise other than through active communication, either in the form of negative or positive feedback loops. The second argument arose from noting the dialectic relationships among the original classes and extending this to the antithesis of Kantor and Lehr's Open model.

The added taxon, the absolute antithesis of the Open paradigm, is organized around harmony or quiet efficiency and was given the taxonym Synchronous. Rather than feedback communication, it predominantly relies for its coordination of collective process on extant mental models, that is, that participants already have sufficiently well-developed models of each other, their relationships, and their roles in collective activity to reduce or minimize the need for explicit communication. Information theory has established that shared mental models can substitute for actual active communication; when the receiver of messages has a predictive model of the transmitter, as that model approaches perfect prediction, the bandwidth necessary to communicate messages approaches zero (Conant 1979). In other words, if one person already knows what another is going to say, the other does not have to say it. In practice, mental models will necessarily be incomplete and inaccurate to some degree, so prediction will be imperfect. As the accuracy and richness of shared mental models increases, the need for active communication diminishes.

In pursuit of a complete taxonomy, application of recursive-dialectic logic eventually established that five taxa were necessary and sufficient to account for all possible patterns of group coordination (Constantine 1988, 2025a, b). In outline, the analysis is as follows.

Within the domain, D, of coordination of human systems, the values for the defining attribute A_1, dominant coordinating mechanism, are: (1) negative feedback, (2) positive feedback, (3) negative and positive feedback, (4) mental models (neither negative nor positive feedback), (5) negative and positive feedback along with shared mental models.

T_1 = {negative feedback, **stability**}
T_2 = {positive feedback, **variety** (i.e., not stability)}
T_3 = {positive feedback and negative feedback, **adaptability** (both stability and variety)}
T_4 = {shared mental models (neither positive nor negative feedback), **harmony** (quiet efficiency, not adaptability)}
T_5 = {shared mental models with negative and positive feedback, **comprehension** (adaptability and harmony achieved through consensual construction of common understanding of reality, the internal and external environment)}
T_6 = {not shared mental models, not negative feedback, not positive feedback}, that is, no means of coordination of sustained, patterned collective behavior, therefore not a human system as defined

In other words, five taxa are necessary and sufficient to cover all possible forms of human systems based on how they are coordinated along with their corresponding organization, operation, and orientation (the Congruence Principle). The fifth taxon was given the taxonym Unified because it is the absolute synthesis of Synchronous with Open, in turn the absolute synthesis of Closed and Random, that is, integrating through emergence aspects of all of the previous taxa. Its characteristics identified in the last column of Table 2 are derived from purely theoretical and logical arguments and have largely yet to be confirmed (Constantine 2025b).

This closes the conceptual domain in the sense of bounding the space based on possible mechanisms of coordination of human activity. Other taxonomies grounded in other underlying theory or alternative starting points are, of course possible. In this taxonomy, construction of a dimensioned property space as shown in Fig. 5 makes it possible to demonstrate how Social Coordination Theory provides a single explanatory foundation underlying the typologies and defining dimensions of diverse models (Constantine 1993; 2025a; b), including, for example, family types (Olson 2000), parenting styles (Baumrind 1971), and shared construction of reality (Reiss 1981). By anchoring the taxonomy and underlying theory in the simplest, fewest, most fundamental concepts—mechanisms of coordination—the taxonomy ultimately applies to all possible forms of human socio-cultural systems at all scales, from families and town councils to small businesses and global enterprises, from fire brigades to religious institutions.

In taxonomy, differentiae represent unique attributes intrinsic to a taxon that distinguish it from all other taxa. These measures derive from the taxonomy as answers to the question of what characteristics or properties in terms of organization or operation differentiate a taxon from all the other taxa.

For example, the Random paradigm in its decision making, problem solving, and collective behavior in general routinely considers completely disparate and independent actions or choices by all participants as a fully acceptable collective outcome or solution. This characteristic is designated as *divergence*. By contrast, the Closed paradigm is based on acceptance of a single solution or choice according to authority and tradition. Open paradigm decision making and problem solving rest on collaboration to reach a single shared consensus on the course of action or solution to a problem. Within the Synchronous paradigm, a common solution or action rests on the already shared assumptions within its members' common mental models. The Unified paradigm actively builds such a shared reality through collaborative ongoing validation of common models anchored in its external and internal environments.

In the analytical (geometric) interpretation of this recursive-dialectic taxonomy of socio-cultural systems, the differentiae correspond to vectors normal to each face to the opposite vertex (Fig. 6). Note that the differentia for the fifth taxon, the Unified paradigm, cannot be directly depicted in this representation of the 3-dimensional property space, a tetrahedron, as this vector lies in 4-dimensional property space, a 4-*simplex.* The differentiae here (bottom row of Table 2) distinguish taxa on the basis of distinctive features of the process by which such systems are regulated.

Hierarchy—intrinsic hierarchy of authority and control

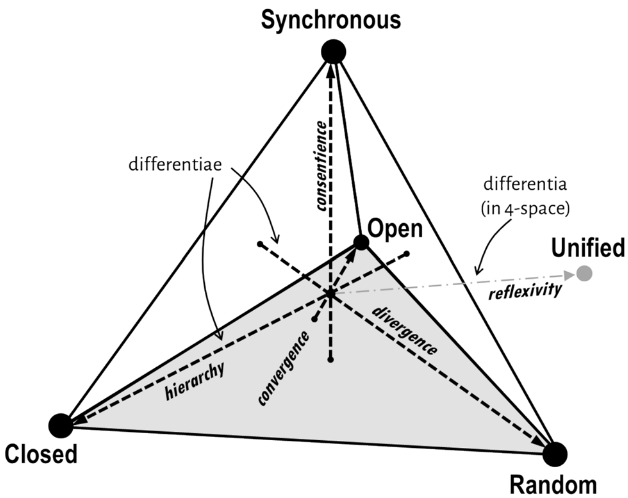

Fig. 6 Analytical geometry of the social coordination theory taxonomy showing differentiae (adapted from Constantine 2025a, b)

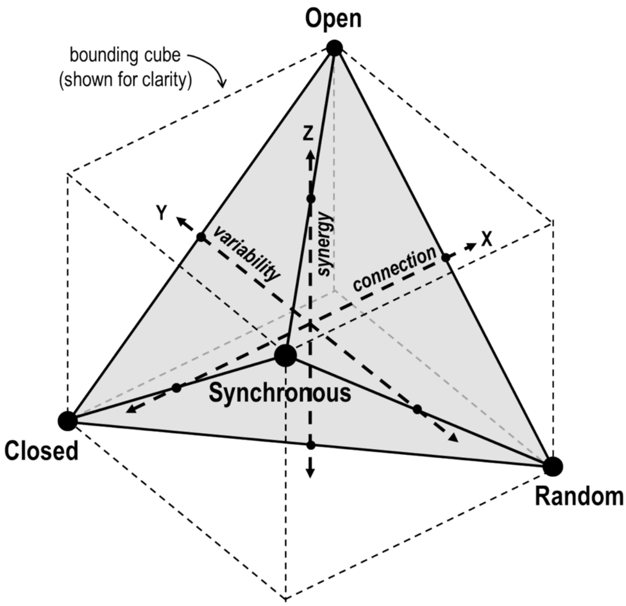

Fig. 7 Process dimensions of the four-taxon coordination theory taxonomy (adapted from Constantine 2025a, b)

Divergence—divergent process with individual solutions accepted as conjoint resolution
Convergence—convergent process through collaborative consensus-building toward common solution
Consentience—alignment through extant shared mental models and the experience of internal agreement
Reflexivity—self-reflective, self-referential process actively building shared models of reality, including of the system itself and of its participants

As in biological taxonomy, multiple properties or attributes may function as differentiae. If the objective is building and elaborating explanatory theory, differentiae that constitute a conceptually consistent set across taxa and are closely connected with underlying theory are preferable to ones that are merely heuristic. The differentiae in the Paradigmatic Framework identified here comprise distinguishing differences in problem solving and decision making, which are clearly tied to coordination of collective activity.

Process dimensions intrinsic to the 4-taxon taxonomy (Fig. 7) are defined by joining midpoints of opposite edges of the property space and represent contrasts between pairs of taxa. Within Social Coordination Theory these are:

Connection—extent of active engagement between actors: high in Open- and Closed-paradigm systems and low in Random- and Synchronous-paradigm systems in which participants are more separate and disengaged
Variability—process variation over time: high in Random- and Open-paradigm systems and low in Closed- and Synchronous-paradigm systems

Synergy—intrinsic balance/equating of individual and collective needs and interests: high in Open- and Synchronous-paradigm systems and low in Closed- and Random-paradigm systems, which skew substantially toward either the collectivity (Closed) or the individual (Random)

The goal in defining these dimensions is to identify pair-wise distinctions that are strongly related to underlying theory and assumptions, the more elementary the better. This is the art in the science of taxonomy. In this case, variability and connection are particularly basic descriptors of aspects of group process that, owing to their elementary nature, enable straightforward mapping of the Paradigmatic Framework into a number of other distinct models of, for example, family process (Constantine 2025a, b).

The choice for C = Closed for the starting point in the formally derived RDT warrants a closer look. Historically, it arises from the original observations and analysis by Kantor and Lehr (1975), but it is worthwhile considering alternatives. Starting the series with C = Random makes no difference because |¬| (|¬|x) = x. Beginning with C = Open generates the taxonomy of Open, Synchronous, and Unified, omitting the empirically established taxa of Closed and Random. Again, since |¬| (|¬|x) = x, the same taxonomy results from starting with C = Synchronous. Finally, starting with C = Unified results in a single class, since the absolute antithesis of Unified is "non-system," that is one lacking any mechanism for coordination. There may be other arguments for regarding the Closed taxon as a preferred starting point for the derivation.

In general, development of any RDT should include examination of the consequences of varied starting classes for C. If the taxonomy is to be both empirically based and theoretically sound, the choice of C and its absolute antithesis should reflect real-world data along with fundamental theoretical constructs and arguments. In the case of the Paradigmatic Framework, Social Coordination Theory points to the Closed paradigm as the simplest or most likely coordination scheme for the generation of sustained patterned collective behavior of human systems.

4 Conclusions

Although dialectical reasoning and argumentation in their varied incarnations have a rich and protracted history in the development, elucidation, and refinement of concepts and categories in numerous fields, extensive searches of the literature of dialectics, taxonomy, and typology have so far failed to uncover direct precedents for the use of restricted definitions of dialectical logic to directly generate a formal taxonomy. It is thus possible that the approach described in this paper is, at least in part or in some aspects, novel.

Taxonomy development through application of a recursive-dialectic function may offer an approach to theory construction of broad potential, particularly in the social and behavioral sciences but also potentially in the information and systems sciences. This approach offers distinctive advantages in merging within a single model both taxonomic and typological features, including differentiae and typological dimensions derived from and directly related to the underlying theoretical basis of the classification itself.

The validity and utility of the RDT approach is evidenced by its application in the evolution of Social Coordination Theory and the Paradigmatic Framework, in which the resultant taxonomy successfully predicted and described taxa that had not previously been identified. Moreover, the taxonomy has supplied a common simpler and more fundamental theoretical framework linking and explaining several other established and well researched models, including models of family functioning, parenting styles, and problem solving (Constantine 2025a, b).

Generalization from an N of 1 is necessarily fraught, but in this case the potential for broader application does not rest on having multiple extant examples but stems from the nature of recursive-dialectic logic itself. Because of its construction from a recursive logic, in principle, the RDT is potentially of use to elaborate and identify additional possible taxa for any conceptual or analytic classification that includes a pair of classes distinguished as polar opposites or by binary opposition.

For example, Gelfand's (2018) well-validated tight-loose culture model, based on the number of rules and their degree of enforcement, is worth considering, particularly as cultural norms and their enforcement are clearly related to coordination mechanisms, that is, they serve to regulate patterned collective behavior. The relationship between the Gelfand model and the paradigmatic taxonomy is worth further exploration, particularly as Gelfand (Gelfand 2021; Gelfand et al. 2017) has argued on the basis of empirical evidence that the tight-loose culture model is "fractal," that is, like Social Coordination Theory, it is a scale-independent model, applicable to human groups of all sizes.

A major difference between the RDT approach and widely used statistical clustering techniques for taxonomy construction lies in how the number of taxa is determined. In the RDT approach, the number of taxa is determined when the domain is fully covered by maximally conceptually distinct classes that are distant from each other in concept space and hence represent more or less clean semantic distinctions that can be readily related to or used in developing or refining sound explanatory theory. This method also ensures completeness. Within the assumptions of the underlying theory and enforcement of maximal conceptual difference, with complete expansion of the series all possible taxa are identified without inclusion of taxa outside the chosen domain.

In contrast, common statistical clustering techniques, even those more closely related to RDT, such as archetype analysis (Cutler and Breiman. 1994), the number of clusters included is not only intimately dependent on the particular data set analyzed but also on judgment calls by researchers based on inspection, such as the "elbow method" (Thorndike 1953), widely used despite well-known limitations and strong criticisms (e.g., Schubert 2023).

4.1 Limitations

As with all tools and techniques of classification and theory construction, the RDT approach has its limitations. Most importantly, the approach is a means for exploring and defining classes within a conceptual space beginning with one or more already established classes and therefore is dependent on the choice of domain and initial class(es) and the clarity with which these are defined. The absolute antithesis of a thesis, and all subsequent taxa in an RDT, will only be as clear and well-defined as the thesis. Fuzzy constructs and muddled conceptualization will propagate through the emerging taxonomy. If the starting point is not or cannot be anchored in some fundamental framework, the explanatory potential of the resulting taxonomy will necessarily also be compromised.

This limitation is especially important to keep in mind when starting from results of a purely heuristic statistically derived classification. Such results may be statistically sound, accounting for a significant portion of the variance with low variance within clusters and high variance between clusters, but without a readily apparent conceptual basis. Difficulty in coming up with simple, straightforward, and evocative names or descriptors for identified classes can be indicative of this problem. A statistical model in which no two identified clusters or factors approximate binary opposition could also be a problematic starting point for constructing an RDT.

It is worth considering, however, that generating an RDT from a weak starting point could nevertheless be a useful exercise for exploring the concept space toward discovering potential explanatory theory that might have been obscured by the particular data set, the sampling technique, or even by the specific statistical methods employed. The differences between the taxa of such a trial RDT and those found in statistically identified classes would require examination and explanation which, in turn, could illuminate the way toward an underlying explanation.

4.2 Protocol

A formal step-by-step method would, at this juncture, perhaps be a step too far, but based on experience developing the Paradigmatic Framework a general approach can be outlined.

(1) Clean up definitions and descriptors and clarify a posited theoretical basis. A proposed underlying theoretical foundation should be identified comprising the fewest, simplest, and most basic fundamental elements that could account for empirically evident classes. If the goal is broadly applicable theory, as was the case with social coordination theory and the paradigmatic framework, definitions should be, as much as possible, independent of specific cultural/regional/ethnic context or assumptions.

(2) Select an appropriate candidate for an initial thesis, C, drawing on both empirical findings and theoretical arguments. The starting point for development of an RDT is a pair of classes defined or characterized as polar opposites at least one of which, but preferably both, is supported by empirical evidence. If the available empirical evidence does not include a pair of polar opposites, then the absolute antithesis of C will need to be constructed conceptually. It is important that the initial thesis and its absolute antithesis be defined and described as cleanly and consistently as possible.

(3) From this starting point, a provisional RDT can be developed as described in this paper. The recursive dialectic series is expanded until the domain is exhausted, that is, a null case, empty set, or term not in the chosen domain is generated.

(4)The provisional RDT should be refined conceptually by naming each taxa appropriately, by distinguishing core and defining features and attributes from derived characteristics, as in Table 2, and by using consistent terminology across and within taxa.

(5) The theory should be further clarified by identifying, naming, and defining differentiae for the taxa of the RDT property space, along with derived orthogonal dimensions for that property space if possible. It should be noted that any taxonomy that admits mixtures of taxa or intermediate forms can be modeled as compositional data and therefore transformed into a *k*-simplex that can be treated for purposes of statistical analysis as an Aitchison space (Aitchison 1982; Egozcue and Pawlowsky-Glahn 2019; Pawlowsky-Glahn and Egozcue

2001). The RDT approach is distinctive in directly linking this property space to underlying theory of the phenomena being modeled.

(6) The provisional RDT should be tested against and refined through additional data, observations, and experiments, particularly toward confirmation or disconfirmation of predicted taxa, properties, or relationships. The taxa of the RDT should also be reviewed against the taxonomy serving as a starting point, whether statistically derived or otherwise, and any differences explained or flagged for further investigation.

4.3 Further research

Possibilities for further research fall into two broad areas: (1) research on Social Coordination Theory and (2) research on the Recursive Dialectic Taxonomy as a broadly applicable approach to taxonomy and theory construction. In both cases, the full panoply of research protocols can, of course, potentially be brought to bear. However, some specific directions suggestion themselves.

As for social coordination theory, at this juncture the supporting evidence is largely indirect. It rests primarily on convergence with and explanation of other models for which there is a substantial body of supporting research along with a smaller number of studies on earlier versions of the Paradigmatic Framework. (see Constantine 2025a, b). Next steps in research on SCT include refining existing measures to cover the full taxonomy and direct tests of selected SCT predictions. Some of the latter can be studied with small group experiments along the lines of research linking group dynamics, performance, and collective epistemology (Kruglanski and Webster 1996; Kruglanski et al. 2006). For instance, SCT predicts that human systems organized according to different paradigms will exhibit different characteristic responses to certain kinds extreme challenges. For example, Closed-paradigm groups can be expected to become more rigid and tightly controlled under pressure, while Open-paradigm groups are likely to become caught up in endless cycles of debate and discussion without resolution.

The current version of SCT could be readily falsified in a number of ways (Constantine 2025b). These include, for example, discovering or demonstrating a mechanism for social coordination other than by feedback communication and shared internal models.

Regarding the RDT approach in itself, some exploratory opportunities might involve only modest resources. Developing a complete and well-formed candidate RDT is a nontrivial process, as the experience leading to the Paradigmatic Framework shows, but it is largely conceptual, a desk exercise that need not involve new laboratory or field research. The potential of an RDT to extend an existing dichotomous model has already been mentioned. Even without new empirical studies, it is possible that an RDT could expose promising new lines of research or potential explanations for previously unresolved questions.

Another possibility is constructing an RDT starting with an existing purely heuristic statistical taxonomy in order to explore whether an RDT can expose new insights into the domain or lead to potential explanation. In addition to the taxa in and of themselves, the derived differentiae and typological dimensions can be of interest as candidates for scale development, for highlighting limitations of extant heuristic classifications, and, of course, as way pointers for building theory. Theoretical predictions derived from an RDT create new opportunities for testing, whether on the existence of previously unrecognized taxa or properties, or regarding the relationships among variables.

In the final analysis, the RDT approach offers a possibly novel alternative to conventional classification methods of typology and taxonomy, one that integrates taxonomy, typology, and theory construction within a single systematic process linking the conceptual, the logical, and the analytical. It is hoped that this holds the potential to stimulate fresh insights and new research across multiple disciplines, particularly in the social and behavioral sciences.

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