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# A Guttman-Based Approach to Identifying Cumulateness Applied to Chimpanzee Culture

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## Abstract

Human culture appears to build on itself—that is, to be to some extent cumulative. Whether this property is shared by culture in the common chimpanzee is controversial. The question previously has been approached, qualitatively (and inconclusively), by debating whether any chimpanzee culture traits have resulted from individuals building on one another's work (“ratcheting”). The fact that the chimpanzees at different sites have distinctive repertoires of traits affords a different avenue of approach: determining whether the traits accumulate, site to site, in a structure more orderly than would be expected by chance. Here we use Guttman scalograms and a gamma-type statistic to bring the first quantitative evidence to bear on the question. We show that while traditional methods provide apparent support for a cumulative tendency, our more rigorous methods do not. This may be because cumulateness requires human-like social-learning mechanisms, or because culture generally is not sufficiently unidimensional to scale well. A cumulative tendency would be expected, however, under rather weak assumptions; therefore it seems more likely that chimpanzee culture is cumulative, but this data set is simply too small to evidence it.

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The last thing a science discovers, Whitehead famously remarked, is what it is really about (1911/1958, pp. 166-167). As matter is to physics, or, say, life is to biology: so, perhaps, is culture to anthropology. What kind of a thing is culture? Or perhaps it is more useful to ask: To what kinds of representation does culture seem to lend itself?

The picture of culture, in its diachronic dimension, as a stepwise ascent is an old and venerable one, a fact of which the greatest 19th-century evolutionists were well aware. "Some of the ancient poets and philosophers," remarked Lewis Henry Morgan, had realized that humans had "commenced in a state of extreme rudeness from which they had risen by slow and successive steps" (1877/1985, p. 38). Had Morgan documented his assertion, he could scarcely have improved on this passage—in fact cited by Edward B. Tylor (1924, p. 40)—written in Rome nearly two millennia before:

. . . Then slowly, step by step,  
 The sailor's craft, the tilling of the soil,  
 Walls, laws and arms, roads, dress, and all their ilk,  
 Yea, all life's prizes and its dear delights  
 As well, songs, painted pictures, and the art  
 Of carved and polished images, 'twas use  
 And the bold urge of tireless minds withal  
 That taught them bit by bit, as they progressed  
 With stumbling feet along the upward path.

(Lucretius V: 1448-1457, trans. Bennett, 1946)

In several ways, Lucretius was some eighteen centuries ahead of his times (Harris, 1968, pp. 26-27). When Europe finally did surpass his accurate intuitions by *demonstrating* the generally progressive nature of cultural development, it was by no means mere ethnocentric smugness; it also was a solid scientific refutation of scripturally motivated degenerationism (Tylor, 1865, chapter 7; 1924, chapter 2; cf. Harris, 1968, pp. 54-59).

For the first half of the 20th century, anthropologists tried to deny the value of such representations (Carneiro, 2003, chapter 5); but the revival, around midcentury, of cultural evolutionism brought new affirmations of their accuracy. The archaeologist Albert C. Spaulding, for example, asserted

that “there are stair-steps in culture change, and the steps lead consistently upward” (Spaulding, 1960, p. 454). Cultural evolutionism’s revival brought, in addition to such enthusiastic assertions, actual scientific steps forward; especially noteworthy are (1) the first attempt to quantitatively measure the adequacy of this kind of representation (Freeman & Winch, 1957); (2) improvement and fuller explication of the method (Carneiro, 1962); (3) a large-scale application to ethnological material (Carneiro, 1970); and (4) its extension from ethnological to archaeological data (Peregrine, Ember, & Ember, 2004).

The positive results reported in this small body of research are consistent with the longstanding impression that culture, despite occasional cases of devolution, ordinarily manifests a cumulative kind of process: New culture traits usually build, directly or indirectly, on older ones. If an old one occasionally disappears entirely, the effect is overridden by a greater number having been added to a stock of retained ones; the stock grows over time through *cumulation*—increase by successive addition.<sup>1</sup> Cumulativeness sometimes is interpreted as expressing an underlying property referred to as *homogeneity* (Loevinger, 1947) or *unidimensionality* (McIver & Carmines, 1981; Weller & Romney, 1990); as such, it might be considered a premise of what is known, in anthropological history and theory, as unilinear evolutionism (Carneiro, 2003, pp. 28-31). Often associated with Herbert Spencer and dismissed as anti-Darwinian (cf. Graber, 2007), cumulative evolution in human culture recently is being examined with greater care and rigor (e.g., Currie & Mace, 2011).

Is chimpanzee culture cumulative? The question has begun attracting significant attention, with arguments already being advanced that it is not; that it is; and that it may be, but is at best far less so than human culture. Taking the structural and functional modification of the hammer, by many individuals over many generations, as his exemplar, Michael Tomasello (1999, p. 37) proposes that “ratcheting” of this kind is found only among humans. Against this, William McGrew (2004, pp. 23-24) argues that perfectly good examples of ratcheting can be found even among monkeys, citing especially the sequential modification of wheat-sluicing by the Japanese macaques of Koshima. Whiten, Horner, and Marshall-Pescini (2003, pp. 93-95) suggest that chimpanzee culture, to judge by the apparent differentiation of ant-gathering tools, may be to some degree cumulative. Certainly a like impression is left by the brush-tipped termite-fishing probes described by Sanz, Morgan, and Gulick (2004) and Sanz, Call, and Morgan (2009). One scarcely would assume that the clever chimpanzee who—perhaps upon seeing a probe grow more rather than less effective as its end frayed—first began

prefraying them also had invented termite-fishing itself (cf. Lycett, 2010, p. 254) Whiten adds, however, that that any such cumulateness would seem modest indeed compared to that exhibited by human culture, especially in recent centuries (Whiten, 2009, p. 120).

As these examples show, cumulateness is being thought of as a tendency that would evidence itself in the history of particular cultural features (traits, traditions, etc.). Yet attempting to determine whether one cultural feature or another is a true instance of “ratcheting” is not the only avenue of approach. Each chimpanzee community, after all, also is possessor of a more or less distinctive set—“profile,” “suite,” or “repertoire”—of such features. Here we report a first attempt to find evidence, in these repertoires, of a cumulative tendency. We begin by describing the data used. Next, we characterize the methods that have been used to study cumulateness in human culture by applying them to chimpanzee culture. We then explain what we see as significant deficiencies in these methods, after which we explain our own methods and apply them to the chimpanzee data.

## Data

A landmark paper in *Nature* (Whiten et al., 1999) synthesized 151 person-years of observation of free-ranging chimpanzees at seven sites: Gombe, Mahale M, and Mahale K in Tanzania; Kibale and Budongo in Uganda; Bossou in Guinea; and Tai in Ivory Coast. Noting that while some cultural anthropologists consider linguistic mediation definitionally necessary for phenomena to qualify as cultural, Whiten et al. (1999) employ the less restrictive kind of definition favored by biologists (and many anthropologists): Culture is behavior transmitted repeatedly through social learning, thereby becoming characteristic of a group or population.<sup>2</sup> Growing evidence is suggesting that cultural traditions, so defined, might result from social-learning mechanisms not only simpler than language, but simpler even than imitation (Matthews, Paukner, & Suomi, 2010).

Defining culture is one thing; demarcating culture traits as such is another. Despite such objective-sounding notions from non-anthropologists as “memes” (Dawkins, 1976) and “culturgens” (Lumsden & Wilson, 1981), which in effect make culture entirely mental, and an intriguing proposal by a cultural anthropologist (Harris, 1964), which makes culture mainly behavioral, no fully satisfactory way to identify equivalent units of culture has been found (cf. Kroeber & Kluckhohn, 1952, pp. 319-320). The best solution, unfortunately, remains a consensus of expert opinion. Accordingly, Whiten et al. (1999) used a “complex, collaborative and iterative” process to develop

a list of “candidate cultural variants that were fully and consensually defined” (Whiten et al., 1999, p. 682). In a second phase, they coded each of the 65 variants, for each of the seven sites, into one of six mutually exclusive and exhaustive categories:

- (1) *customary*, for which the behaviour occurs in all or most able-bodied members of at least one age-sex class (such as adult males);
- (2) *habitual*, for which the behaviour is not customary but has occurred repeatedly in several individuals, consistent with some degree of social transmission;
- (3) *present*, for which the behaviour is neither customary nor habitual but is clearly identified;
- (4) *absent*, for which the behaviour has not been recorded and no ecological explanation is apparent;
- (5) *ecological explanation*, for which absence is explicable because of a local ecological feature; and
- (6) *unknown*, for which the behaviour has not been recorded, but this may be due to inadequacy of relevant observational opportunities. (Whiten et al., 1999, p. 682, emphasis added)

Whiten et al.’s operational definition for identifying traits as cultural was that they be “recorded as *customary* or *habitual* in some communities, yet *absent* at others” (Whiten et al., 1999, p. 683, emphasis added). This definition resulted in their eliminating 26 of the 65 variants: 16 by virtue of having been scored as *habitual* or *customary* at none of the sites, seven as having been so scored at all of the sites, and three as having had all their absences scored as *ecological explanation*. These eliminations left 39 variants with claims to cultural status, representing an amount of variation not known to be matched, the authors noted, by any other nonhuman species. These culture traits, moreover, are quite diverse: Some are mere attention-getters; some relate to grooming and courtship; and some involve making and using tools. The authors also noted that the sites exhibit distinctive repertoires of the traits (which fact provides our own point of departure); they also observed that the two western populations (Taï and Bossou) and the five eastern ones, though considered different subspecies (*verus* and *schweinfurthii* respectively), had trait repertoires that differed as much within subspecies as between them—which would be expected, of course, if the behaviors are indeed cultural rather than biological (Lycett, Collard, & McGrew, 2010; but cf. Langergraber et al., 2011).

Our goal of constructing a basic Guttman scalogram requires that we identify a set of *items* (here, culture traits) each of which is scored unambiguously, as present or absent, for every member of a set of *subjects* (here, chimpanzee sites). Clearly, a trait scored (1) or (2) is unambiguously

“present” for our purposes at that site, and a trait scored (4) is unambiguously “absent” from it. Therefore a score of (1), (2), or (4) at all seven sites is necessary for a trait to qualify. Ten traits qualified according to the 1999 scorings; two of these, however (No. 45 Expel/stir and No. 47 Fly-whisk), we have eliminated because their original scores of (4) at Kibale were soon revised to (5) (Whiten et al., 2001, table 3, p. 1495).<sup>3</sup>

Category (3) deserves special comment. This category is ambiguous in that a trait so scored has been observed at the site, and in that sense is present; but not observed routinely enough to achieve cultural status, and in that respect is absent. It might be suggested that from a conceptual standpoint, being merely *present* (3) should be counted as absent inasmuch as the trait has been deemed (by Whiten et al.) not to have achieved cultural status. It might be countered, however, that from a methodological standpoint, distinguishing presence from total absence would be more reliable than discriminating between presence and habitualness; therefore, being *present* (3) should be counted as culturally present. In order to avoid this ambiguity, all traits scored (3) for any site were, as implied above, removed from the data set. After eliminating all traits scored (3), (5), or (6) at any of the seven sites (thereby requiring a score of (1), (2), or (4) at all the sites), we are left with the following eight traits, as numbered and described by Whiten et al. (2001, table 1, pp. 1491-1492 [references to primary literature deleted]):

41 Fluid-dip: Use of probe to extract fluid, including honey and water

43 Marrow-pick: Use of probe to extract contents of bone/skull

44 Lever open [*sic*]: Stout stick . . . used in levering fashion to enlarge insect or bird nest entrance

48 Self-tickle: An object . . . used to probe ticklish areas on self

53 Leaf-clip, mouth: Noisy ripping of leaf, to gain attention for various functions

59 Hand-clasp: Two chimpanzees clasp[ing] hands overhead, grooming each other with the other hand

64 Shrub-bend: Putting stem(s) under foot and squashing, to attract attention of potential mating partner

O	O	1	1	1	1	1	Fluid-dip	(#41)
O	O	O	O	O	O	1	Marrow-pick	(#43)
O	O	1	O	O	O	1	Lever-open	(#44)
O	O	1	O	O	O	O	Self-tickle	(#48)
1	1	O	1	1	1	1	Leaf-clip	(#53)
O	O	O	1	1	1	1	Hand-clasp	(#59)
1	1	O	O	O	1	O	Shrub-bend	(#64)
O	1	1	1	1	1	1	Rain-dance	(#65)
Bs	Bd	Go	Kb	Mk	Ma	Ta		
Sites								

**Figure 1.** Trait presences (1's) and absences (O's) at seven sites

Note: Sites: Bs, Bossou; Bd, Budongo; Go, Gombe; Kb, Kibale; Mk, Mahale K; Ma, Mahale M; Ta, Tai.

65 Rain-dance: At the start of heavy rain, several adult males perform[ing] vigorous charging displays. Displays tend to return the males to their starting position, to be coordinated or in parallel, may include slow charges as well as rapid and may involve a variety of display patterns (Whiten et al., 2001, pp. 1491-1492)

Though these traits are few in number, they appear representative of the range of chimpanzee culture: The variants exemplify not only tool usage, but also patterns of social interaction and affective expression. Figure 1 shows their site distribution.

It might be objected that inspecting the traits does not reveal any that would be expected, logically or intuitively, to stand to one another in cumulative relationships. It therefore must be stressed that our investigation presumes the possibility that evidence for cumulateness can be latent rather than patent in a data set, and as such may require, for its discovery, special tools of just the kind to which we now turn.

## A Conventional Analysis

Guttman scaling attempts to arrange dichotomous data into a scalogram such that the number of presences or “hits” (usually indicated by +’s, X’s, or 1’s) tends to increase, as much as possible, both from row to row and from col-

O	O	+	O	O	O	O	Self-tickle	(#48)
O	O	O	O	O	O	1	Marrow-pick	(#43)
O	O	+	O	O	O	1	Lever-open	(#44)
O	O	-	1	1	1	1	Hand-clasp	(#59)
O	O	1	1	1	1	1	Fluid-dip	(#41)
O	1	1	1	1	1	1	Rain-dance	(#65)
1	1	-	1	1	1	1	Leaf-clip	(#53)
Bs	Bd	Go	Mk	Ma	Kb	Ta		
Sites								

**Figure 2.** Chimpanzee-culture scalogram using conventional methods  
 Note: Each positive error (+) is a trait’s unexpected presence at a site; each negative error (-) is an unexpected absence. Sites: Bs, Bossou; Bd, Budongo; Go, Gombe; Mk, Mahale K; Ma, Mahale M; Kb, Kibale; Ta, Taï.

umn to column. If perfect cumulation inheres in a data set, this procedure allows it to express itself in the form of a regular triangular pattern, or “stair-step,” of hits complemented by an equally regular triangle of misses. Applied to the question of culture’s cumulativeness, this means that if we begin by representing the sites in columns and the culture traits in rows, cumulativeness would consist in a tendency for the traits to “stack” compactly, in higher and higher columns, as we move left to right, from sites with fewer traits to sites having more traits.

An important point to notice is that traits’ “stacking well” at the sites entails that they will “scale well” across the sites. For a scalogram formatted as described above, then, cumulativeness may be thought of dynamically as a tendency for hits simultaneously to settle toward the bottom, and drift toward the right. Traits that scale poorly will tend to be absent at sites exhibiting many traits, while simultaneously being present at sites having few traits (resulting in hits in the upper left). A common practice (to which the Conclusion will revert) is to visually evaluate the scalogram and eliminate any traits that exhibit a conspicuous lack of scalability. Applying this to the chimpanzee data results in the elimination of trait No. 64 (Shrub-bend), leaving the scalogram shown in Figure 2.

Inspection of Figure 2 reveals that the trait repertoires stack perfectly at all sites except Gombe. (One wonders whether Gombe’s exceptionality somehow reflects the long-term and relatively invasive interaction with humans at this site.) Using the Goodenough-Edwards method of error counting (McIver & Carmines, 1981, pp. 42-44), we find only four entries that would need to

be changed to achieve a perfect scalogram ( $CR = .92$ ,  $MMR = .78$ ,  $CS = .64$ , confirmed using Anthropac software [Borgatti, 1992]). Comparing these values with the standards of acceptability under Guttman scaling ( $CR > .9$ ,  $MMR < .9$ ,  $CS > .6$  [McIver & Carmines, 1981, p. 70]), we find that the data seem to suggest that culture, even in this very rudimentary form, already exhibits a cumulative tendency.

## Deficiencies of Conventional Methods

Although traditional methods thus appear to find, in the Whiten et al. chimpanzee data, a measure of support for cumulativeness, there is some question as to the legitimacy of this conclusion. A fundamental problem is that conventional assessment of scalograms relies on a method of quantifying error that appears quite low in face validity. This method consists in simply counting the number of entries that would need to be changed to create a "perfect" scalogram. While this does provide some information about the cumulation in a data set, it takes no account of the *severity* of the errors. To appreciate this problem, let us consider a single site exhibiting three of the possible seven traits, with the presence and absence of traits being indicated, for convenience, in a row instead of a column. Assuming that the traits are cumulative (with common traits on the right and rare traits on the left), the ideal pattern would be (0000111). Now let us compare this ideal pattern with two different patterns, each of which has one trait out of place: (0001011) and (1000011). Under traditional methods, these two patterns would be considered equivalent because each has one trait out of place; and, using the preferred error-counting method (Goodenough-Edwards), each would require change of two entries to match the ideal pattern (viz., of the fourth and fifth entries from the left in the first pattern, of the first and fifth entries in the second). But clearly, the latter pattern deviates farther from the ideal than does the former, because its out-of-place trait is four places, rather than only one place, to the left of the ideal position. The traditional method, then, does not afford an accurate measure of the degree to which observed patterns deviate from ideal ones.

A second deficiency of the conventional approach to Guttman scaling is the absence of a versatile method for determining whether a given scalogram displays cumulation beyond what might be expected to have occurred by chance. Although the guidelines for scalability ( $CR > 0.9$ ,  $MMR < .9$ ,  $CS > .6$ ) attempt to compensate for the expected number of errors in a scalogram, they lack a rigorous statistical underpinning; and it appears that scalograms that, like ours, have fewer than ten items are especially prone to yield high coefficients of reproducibility by chance (Schooler, 1968, p. 297, note 7).

## New Method

In order to quantify the magnitude of error found in a scalogram, let us return to our two imperfect patterns, (0001011) and (1000011). A valid measure must differentiate between these two and indicate that the latter deviates further from the ideal pattern. While there are several methods for defining position, we suggest the use of concordant and discordant pairs. We will begin by defining a concordant pair as any instance within a site where an absence is to the left of a presence (and thus in proper order), and a discordant pair as any instance within a site where an absence is to the right of a presence (and thus out of proper order). To evaluate a site, we total its number of concordant pairs ( $c$ ) and discordant pairs ( $d$ ) (ignoring all pairs that are “unmixed”—that is, composed of two absences or two presences). For the first pattern (0001011) we see there are 11 concordant pairs and only one discordant pair; for the second pattern (1000011) we find eight concordant pairs and four discordant pairs (see Appendix). While it is evident from the concordant and discordant totals alone that the first pattern indeed more closely approximates the ideal one, it proves useful to combine these totals into a single measure, gamma ( $G$ ):

$$G = \frac{c - d}{c + d}$$

This coefficient will take a value of positive one when all pairs are concordant, of negative one when all pairs are discordant, and of zero when concordant and discordant pairs are equal in number. Applying this measure to our two imperfect patterns yields  $G$ 's of .83 and .33 respectively, indicating that the second pattern indeed deviates more from the ideal than does the first.

To measure the quality of cumulation in an entire scalogram, we have only to sum, over all sites, their numbers of concordant and discordant pairs. Thus, we define *scaling gamma* for an entire scalogram:

$$G_s = \frac{\sum c - \sum d}{\sum c + \sum d}$$

The subscript identifies this gamma as measuring not correlation in a bivariate cross-tabulation (as would be expected), but rather the scalability (or cumulation) in a scalogram. Because discordant pairs cannot outnumber concordant pairs in a Guttman scalogram, scaling gamma ranges only from

0	0	1	0	0	0	0	Self-tickle	(#48)
0	0	0	0	0	0	1	Marrow-pick	(#43)
0	0	1	0	0	0	1	Lever-open	(#44)
0	0	0	1	1	1	1	Hand-clasp	(#59)
0	0	1	1	1	1	1	Fluid-dip	(#41)
0	1	1	1	1	1	1	Rain-dance	(#65)
1	1	0	1	1	1	1	Leaf-clip	(#53)
6	10	5	12	12	12	6	# of concordant pairs	
0	0	7	0	0	0	0	# of discordant pairs	
Bs	Bd	Go	Mk	Ma	Kb	Ta		
Sites								

**Figure 3.** Concordant and discordant pair counts for chimpanzee data

Note: Total number of concordant pairs  $[\sum c] = 63$ ; total number of discordant pairs  $[\sum d] = 7$ . Sites: Bs, Bossou; Bd, Budongo; Go, Gombe; Mk, Mahale K; Ma, Mahale M; Kb, Kibale; Ta, Tai.

zero to positive one. The definitions of  $\gamma$  and operations for finding, gamma and scaling gamma as described above are analogous, respectively, to those for zero-order cross-classification gamma (Goodman & Kruskal, 1954; Mueller, Schuessler, & Costner, 1977, pp. 207-220) and partial cross-classification gamma (Davis, 1967).

Hoping to have remedied the problem of error quantification, we turn to the second problem: the need to test for non-randomness. While some work has been done on determining the statistical significance of Goodman and Kruskal’s gamma, it does not directly transfer to scaling gamma in that our concordant and discordant pairs are accumulated differently; we will rely instead on Monte Carlo methods. While a number of models are available for randomizing the scalogram, we have chosen to randomly permute the site locations of the trait presences. This method maintains both the individual trait presences (at 1, 1, 2, 4, 5, 6, and 6) and the total number of presences (at 25).

## Results

Having identified a valid way to quantify scaling error, we may now return to the chimpanzee data to evaluate it for evidence of a cumulative tendency. We begin by looking down each site’s column and determining the number of concordant and discordant pairs. In Figure 3 we see once again that the only errors in the scalogram are at the Gombe site. The number of concordant and discordant pairs—63 and seven, respectively—in the scalogram result in a scaling gamma of .80.

Although a scaling gamma of .80 might seem to suggest cumulateness (see Appendix for direct interpretations of  $G_s$ ), we would like to be assured, before drawing this conclusion, that it is larger than would be expected by chance. For this purpose, 100,000 random permutations of the original scalogram were created and evaluated for cumulation. Of this total, 92,756 permutations yielded scaling-gamma values less than the observed value of .80; 3,149, values equal to .80; and 4,095, values greater than .80. Random permutations evidencing cumulation equal to or greater than that of the observed scalogram thus make up 7.24% of the total, indicating a random probability, for scaling gamma equal to or greater than .80, of .072.

The relatively small size of the scalogram creates some difficulties in evaluating this result in that there are a limited number of values scaling gamma can take (hence the relatively large number of random values at .80). In addition, the small size also allows a single site (such as Gombe) to exert a large influence on the analysis. Still, it seems clear that while traditional methods suggested a rather good case for cumulateness, our more rigorous approach demonstrates that the scalogram does not differ as much from random expectation as required by the most common convention ( $p < .05$ ).

## Discussion

To articulate our work with the wider, ongoing theoretical interest in the question of cumulateness (a form of unidimensionality) in chimpanzee culture, our approach has been essentially deductive. An a priori theoretical interest has entailed asking only one thing of the data: Do they, or do they not, provide evidence for a cumulative tendency? A broadly inductive approach, however, would ask a more general question: What patterns of relationship can be found within the data? While a full exploration of the possibilities goes beyond the scope of this paper, a correspondence analysis was run using Unicet software (Borgatti, Everett, & Freeman, 2002). Of special relevance is the fact that while a data set that forms a good Guttman scale will result in a correspondence model with a dominant first dimension (Weller & Romney, 1990, pp. 79-83), these data produce a model in which a second dimension is quite strong relative to the first (accounting, respectively, for 27.6% and 36.6% of the total variance).

Inspection of Figure 1 immediately discloses the entailment (if-then) relationships within the data set. Two of these relationships should be interpreted cautiously because they involve traits found in only one of the groups (No. 64 [Self-tickle] and No. 43 [Marrow-pick]). These traits are part of a chain that

includes No. 44 (Lever-open), with two presences; No. 41 (Fluid-dip), with five presences; and No. 65 (Rain-dance), with six presences. This, however, is not the only chain. Others include the following: (1) If No. 59 (Hand-clasp) is present, so also is No. 53 (Leaf-clip) (four and six presences, respectively); (2) if No. 64 (Shrub-bend) is present, so also is No. 53 (Leaf-clip) (three and six presences, respectively); and (3) if No. 59 (Hand-clasp) is present, so also is No. 41 (Fluid-dip) (four and five presences, respectively). These relationships appear to play a key role in making the structure two-dimensional rather than unidimensional. (It might be noted that dropping trait No. 64 [Shrub-bend], as was done in the conventional analysis, would remove an interesting part of the data structure.)

A limitation of such exploratory “dredging techniques” is the fact that the absence of definite *a priori* hypotheses makes the results difficult to evaluate objectively (Bernard, 2006, p. 689). In particular, we do not know the probability of a multidimensional model at least this “good” resulting by chance.

## Conclusion

We believe that the position measure  $G_s$  should be considered as an alternative to CR, MMR, and CS for measuring the cumulation in a scalogram. Accompanied by an associated  $p$  value, it provides a more rigorous treatment than do traditional methods. For the chimpanzee data at hand, this more rigorous method yields results that are perhaps disappointing to those of us who would prefer to stress what we share with, rather than what separates us from, our closest relatives. Although the observed  $p$  value of .072 approaches the conventional significance level of .05 (and attains the 0.10 level defensible when, as here, Type I Error seems more acceptable than Type II), certainly the evidence does not support a strong case that chimpanzee cultural is cumulative. It must also be recalled that at the outset of our analysis, we deleted a trait precisely because it scaled poorly. Such deletion has been practiced from the very first application of Guttman scaling to culture traits (Freeman & Winch, 1957, p. 464). This procedure, after all, is often an essential step in developing research instruments; and Guttman scaling and kindred techniques have deep roots in such applications in psychology, social psychology, education, and political science (e.g., Goodenough, 1944; Guttman, 1950; Loevinger, 1947; Mokken, 1971).<sup>4</sup>

It may prove helpful, however, to distinguish more clearly and consistently between research aimed at developing an instrument, and research aimed at identifying cumulateness in a natural phenomenon. For the

latter, it is important to include (or at least represent in a sample), as much as possible, everything that meets the definition of the phenomenon being studied (Durkheim, 1895/1982, p. 75). Deleting traits found to scale poorly necessarily will produce an apparent increase in cumulateness; this increase, however, will have been not discovered but created. Restoring the deleted trait (No. 64 Shrub-bend) results in reduction of  $G$  to .686, with an increase of the random probability to .524—very near the center of the random distribution. More warranted than the conclusion that chimpanzee culture (in general) is cumulative, then, would be the conclusion only that chimpanzee culture traits can be selected such that cumulateness will be exhibited. This is a decidedly weaker conclusion; but at least it is an empirical result, in the sense that we can imagine having found it impossible to create such a scalogram.

In failing to find definite evidence for a cumulative tendency in chimpanzee culture, we leave open the possibility that a cumulative tendency actually does require social-learning mechanisms beyond the abilities of even our closest relatives; perhaps it requires essentially human symbolizing ability, a possibility asserted long ago (White, 1942) and repeated recently (Donald, 1991; Galef, 2009). In any case, experimental approaches are beginning to shed light on the question (e.g., Lehner, Burkhart, & van Schaik, 2011; Marshall-Pescini & Whiten, 2008). It is also possible that the presupposition that human culture (in general) *is* cumulative is itself not entirely warranted. Fundamentally characteristic of culture, be it chimpanzee or human, may after all be a tendency for whatever cumulative sectors it comprises (such as technology or political integration) to be obscured or even overwhelmed by non-cumulative ones (such as modes of affective expression or religious beliefs) (cf. Moore, 1954). Culture, taken as a whole, may be fundamentally heterogeneous—that is, less unidimensional than multidimensional.

What seems more likely, however, is that culture, even taken as a whole, does have a cumulative tendency. Cumulateness, after all, requires no more than that less-frequent traits tend to occur at sites along with, rather than instead of, more-frequent traits. From this perspective, a cumulative tendency might be considered a warranted presumption. The fact that so small a data set has failed to produce evidence for a cumulative tendency scarcely constitutes strong evidence *against* such a tendency. Future research seems bound to clarify the picture. For the near term, we suggest that it may be worthwhile to reexamine past work using the more rigorous methods demonstrated here. Such a reexamination should help us gain a clearer idea of the cumulative model's value for representing cultural evolution, and therefore of just what it is that anthropology is about.

## Appendix

### Scaling Gamma

Under scalability, concordant pairs are represented by any nonidentical trait-to-trait comparisons within a site where the rarer trait is absent and the more common trait is present, while discordant pairs occur any time the rarer trait is present and the more common trait is absent. Returning to Gombe, we find five nonidentical comparisons where the more common trait is present (43-44, 43-41, 43-65, 59-41, 59-65 ) and seven comparisons where the rarer trait is present (48-43, 48-59, 48-53, 44-59, 44-53, 41-53, 65-53).

Go	1	0	1	0	1	1	0
	48	43	44	59	41	65	53

This within-site identification of concordant and discordant pairs is directly analogous to the traditional cross-classification methodology if the presence and absence of traits at each given site are decomposed into two rows. Expanding the above information into its presence-absence components and evaluating each cell for concordant items (falling below and right) and discordant items (falling below and left) yields  $c = 5$  and  $d = 7$ .

	48	43	44	59	41	65	53
A	0	1	0	1	0	0	1
P	1	0	1	0	1	1	0

$$\text{concordant} = 0(0 + 1 + 0 + 1 + 1 + 0) + 1(1 + 0 + 1 + 1 + 0) + 0(0 + 1 + 1 + 0) + 1(1 + 1 + 0) + 0(1 + 0) + 0(0) = 5$$

$$\text{discordant} = (1) + 0(1 + 0) + 1(1 + 0 + 1) + 0(1 + 0 + 1 + 0) + 0(1 + 0 + 1 + 0 + 1) + 1(1 + 0 + 1 + 0 + 1 + 1) = 7$$

Under the assumed model, each randomization maintains the individual trait counts found in the original scalogram, thus conserving the instances of

rare and common traits. Under this constraint, the location of the presences is randomized and the distribution of resulting gamma values can be interpreted as the likelihood that the given traits would “stack” as well as they did by random chance. Figure A1 illustrates a single realization of the Monte Carlo simulation ( $G_s = 0.737$ ); similar scalograms are generated to create the 100,000 values used in the significance calculation.

O	O	O	O	O	O	1		(#48)
O	O	O	O	O	1	O		(#43)
O	O	O	O	1	O	1		(#44)
O	O	1	1	1	1	O		(#59)
1	O	O	1	1	1	1		(#41)
1	1	1	1	O	1	1		(#65)
O	1	1	1	1	1	1		(#53)
8	10	11	12	9	9	7		# concordant
2	0	1	0	3	1	3		# discordant
Mk	Ma	BS	Ta	Ba	Kb	Go		
Sites								

Gamma is a proportional-reduction-in-error (PRE) statistic that indicates the reduction in error produced by using the assumption of scalability to reproduce the matrix (as compared to random guessing). Under naïve guessing, a coin would be flipped to determine which trait is present and which is absent for the ( $n$ ) nonidentical pairs, resulting in ( $n/2$ ) expected errors. Under the assumption of scalability it would be assumed that the trait with the higher marginal probability is present in all non-identical pairings, which would result in an error any time a discordant pair ( $d$ ) existed in the scalogram. Noting ( $n = c + d$ ), we see that Gamma is mathematically equivalent to the reduction in errors from using naïve guessing ( $n/2$ ) to that of scalability ( $d$ ).

$$G = \frac{c - d}{c + d} = \frac{(c + d) - 2d}{c + d} = \frac{n - 2d}{n} = \frac{\frac{n}{2} - d}{\frac{n}{2}}$$

For the chimpanzee data, we have ( $n = 70$ ) nonidentical pairs, resulting in 35 expected errors. Using the assumption of scalability the number of errors created when reproducing the matrix is reduced to seven ( $d = 7$ ), resulting in an 80% reduction in errors.

## Authors' Note

R. B. G. constructed the scalograms, adapted gamma for scalogram analysis, and proposed testing for significance using randomization; D. R. D. specified the randomization, and programmed and executed it; M. L. B. contributed the correspondence analysis.

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## Notes

1. Though this increase theoretically could be arithmetic, intuition suggests that in the case of culture it would be geometric. "Human progress, from first to last, has been in a ratio not rigorously but essentially geometrical" (Morgan, 1877/1985, p. 38). While it would be unrealistic to expect to detect this with small data sets, the large scalogram of human culture presented by Carneiro (1970, Figure 3, pp. 840-841) does indeed display the upward concavity characteristic of geometric growth.
2. The authors refer variously to the chimpanzees at the sites as "populations," "communities," or "groups," depending on the context.
3. The two lesser-known sites added in 2001 had so many traits scored (6) that including the sites would have further eroded our sample of traits. Further revisions of the data, made many years later and for an article by a somewhat different team of authors (Langergraber et al., 2011), we have chosen not to use.
4. We suspect that quantifying error subjectwise rather than itemwise also reflects these roots in instrument-construction; this choice may deserve reconsideration for applications such as ours.

## References

- Carneiro, R. L. (1962). Scale analysis as an instrument for the study of cultural evolution. *Southwestern Journal of Anthropology*, *18*, 149-169.
- Carneiro, R. L. (1970). Scale analysis, evolutionary sequences, and the rating of cultures. In R. Naroll & R. Cohen (Eds.), *A handbook of method in cultural anthropology* (pp. 834-871). New York, NY: Columbia University Press.

- Carneiro, R. L. (2003). *Evolutionism in cultural anthropology: A critical history*. Boulder, CO: Westview.
- Currie, T. E., & Mace, R. (2011). Mode and tempo in the evolution of socio-political organization: reconciling “Darwinian” and “Spencerian” evolutionary approaches in anthropology. *Philosophical Transactions of the Royal Society B*, 366, 1108-1111. doi:10.1098/rstb.2010.0318
- Davis, J. A. (1967). A partial coefficient for Goodman and Kruskal’s gamma. *Journal of the American Statistical Association*, 62, 189-193.
- Dawkins, R. (1976). *The selfish gene*. New York, NY: Oxford University Press.
- Donald, M. (1991). *Origins of the human mind: Three stages in the evolution of culture and cognition*. Cambridge, MA: Harvard University Press.
- Durkheim, E. (1982). *The rules of sociological method* (S. Lukes, Ed., W. D. Halls, Trans.). New York, NY: Free Press. (Original work published 1895)
- Freeman, L. C., & Winch, R. F. (1957). Social complexity: An empirical test of a typology of societies. *American Journal of Sociology*, 62, 461-466.
- Galef, B. G. (2009). Culture in animals? In K. N. Laland & B. G. Galef (Eds.), *The question of animal culture* (pp. 222-246). Cambridge, MA: Harvard University Press.
- Goodenough, W. H. (1944). A technique for scale analysis. *Educational and Psychological Measurement*, 4, 179-190.
- Goodman, L. A., & Kruskal, W. H. (1954). Measures of association for cross classifications. *Journal of the American Statistical Association*, 49, 732-764.
- Graber, R. B. (2007). Bye-bye baby! A cultural evolutionist’s response to evolutionary culture theorists’ complaints. *Social Evolution & History*, 6(2), 1-28.
- Guttman, L. L. (1950). The basis for scalogram analysis. In S. A. Stouffer, L. Guttman, E. A. Suchman, P. F. Lazarsfeld, S. A. Star, & J. A. Claasen (Eds.), *Measurement and prediction* (pp. 60-90). Princeton, NJ: Princeton University Press.
- Harris, M. (1964). *The nature of cultural things*. New York, NY: Random House.
- Harris, M. (1968). *The rise of anthropological theory*. New York, NY: Thomas Y. Crowell.
- Kroeber, A. L., & Kluckhohn, C. (1952). *Culture: A critical review of concepts and definitions*. New York, NY: Random House (Vintage Books).
- Langergraber, K., Boesch, C., Inoue, E., Inoui-Murayama, M., Mitani, J. C., Nishida, T., ... Vigilant, L. (2011). Genetic and “cultural” similarity in wild chimpanzees. *Proceedings of the Royal Society B*, 278, 408-416. doi:10.1098/rspb.2010.1112
- Lehner, S. R., Burkhart, J. M., & van Schaik, C. P. (2011). Can captive orangutans (*Pongo pygmaeus abelii*) be coaxed into cumulative build-up of techniques? *Journal of Comparative Psychology*, 125, 446-455. doi:10.1037/a0024413
- Loevinger, J. (1947). A systematic approach to the construction and evaluation of tests of ability. *Psychological Monographs*, 61(4), 1-49.

- Lumsden, C. J., & Wilson, E. O. (1981). *Genes, mind, and culture: The coevolutionary process*. Cambridge, MA: Harvard University Press.
- Lycett, S. J. (2010). The importance of history in definitions of *culture*: Implications from phylogenetic approaches to the study of social learning in chimpanzees. *Learning and Behaviour*, *38*, 252-264. doi:10.3758/LB.38.3.252
- Lycett, S. J., Collard, M., & McGrew, W. C. (2010). Are behavioral differences among wild chimpanzee communities genetic or cultural? An assessment using tool-use data and phylogenetic methods. *American Journal of Physical Anthropology*, *142*, 461-467. doi:10.1002/ajpa.21249
- Marshall-Pescini, S., & Whiten, A. (2008). Chimpanzees (*Pan troglodytes*) and the question of cumulative culture: An experimental approach. *Animal Cognition*, *11*, 449-456. doi:10.1007/s10071-004-0239-6
- Matthews, L. J., Paukner, A., & Suomi, S. J. (2010). Can traditions emerge from the interaction of stimulus enhancement and reinforcement learning? An experimental model. *American Anthropologist*, *112*, 257-269. doi:10.1111/j.1548-1433.2010.01224x
- McGrew, W. C. (2004). *The cultured chimpanzee: Reflections on cultural primatology*. Cambridge, UK: Cambridge University Press. doi:10.2277/0521535433
- McIver, J. P., & Carmines, E. G. (1981). *Unidimensional scaling* (SAGE University Paper series on Quantitative Applications in the Social Sciences, 07-024). Beverly Hills, CA: Sage.
- Mokken, R. J. (1971). *A theory and procedure of scale analysis with applications in political research* (Methods and Models in the Social Sciences, 1). The Hague, Netherlands: Mouton.
- Moore, H. C. (1954). Cumulation and Cultural Processes. *American Anthropologist*, *56*, 347-357.
- Morgan, L. H. (1985). *Ancient society*. Tucson: University of Arizona Press.
- Mueller, J. H., Schuessler, K. F., & Costner, H. L. (1977). *Statistical reasoning in sociology* (3rd ed.). Boston, MA: Houghton Mifflin.
- Peregrine, P. N., Ember, C. R., & Ember, M. (2004). Universal patterns in cultural evolution: An empirical analysis using Guttman scaling. *American Anthropologist*, *106*, 145-149.
- Sanz, C., Call, J., & Morgan, D. (2009). Design complexity in termite-fishing tools of chimpanzees (*Pan troglodytes*). *Biological Letters*, *5*, 293-296. doi:10.1098/rsbl.2008.0786
- Sanz, C., Morgan, D., & Gulick, S. (2004). New insights into chimpanzees, tools, and termites from the Congo Basin. *American Naturalist*, *164*, 567-581.
- Schooler, C. (1968). A note of extreme caution on the use of Guttman scales. *American Journal of Sociology*, *74*, 296-301.

- Spaulding, A. C. (1960). The dimensions of archaeology. In G. E. Dole & R. L. Carneiro (Eds.), *Essays in the science of culture in honor of Leslie A. White* (pp. 437-456). New York, NY: Thomas Y. Crowell.
- Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
- Tylor, E. B. (1865). *Research into the early history of mankind and the development of civilization*. London, UK: John Murray.
- Tylor, E. B. (1924). *Primitive culture: Researches into the development of mythology, philosophy, religion, language, art, and custom. Two volumes in one* (7th ed.). New York, NY: Brentano's.
- Weller, S. C., & Romney, A. K. (1990). *Metric scaling: Correspondence analysis* (SAGE University Paper series on Quantitative Applications in the Social Sciences, 07-075). Newbury Park, CA: Sage.
- White, L. A. (1942). On the use of tools by primates. *Journal of Comparative Psychology*, 34, 369-374.
- Whitehead, A. N. (1958). *An introduction to mathematics*. New York, NY: Oxford University Press (Galaxy Books).
- Whiten, A. (2009). The identification and differentiation of culture in chimpanzees and other animals: From natural history to diffusion experiments. In K. N. Laland & B. G. Galef (Eds.), *The question of animal culture* (pp. 99-124). Cambridge, MA: Harvard University Press.
- Whiten, A., Goodall, J., McGrew, W. C., Nishida, T., Reynolds, V., Sugiyama, Y., . . . Boesch, C. (1999). Cultures in chimpanzees. *Nature*, 399, 682-685.
- Whiten, A., Goodall, J., McGrew, W. C., Nishida, T., Reynolds, V., Sugiyama, Y., . . . Boesch, C. (2001). Charting cultural variation in chimpanzees. *Behaviour*, 138, 1481-1516.
- Whiten, A., Horner, V., & Marshall-Pescini, S. (2003). Cultural panthropology. *Evolutionary Anthropology*, 12, 92-105. doi:10.1002/evan.10107

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