

# VISIBLE LANGUAGE

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*Cover:* An Incan quipu in the collection of the Peabody Museum of Archaeology and Ethnology, Harvard University, one of the quipu discussed (see especially page 355) by Marcia and Robert Ascher in their article, "The Quipu as a Visible Language."

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# What Is the Proper Characterization of the Alphabet?

## I. Desiderata

W. C. Watt

To a point, an alphabet can be viewed as a "language" and described by a "grammar"; however, since for any such language many different grammars are possible, to take the "linguistic" analogy seriously is to want to find criteria for judging which "correct" grammar is "best." If we grant that the alphabet's users have some systematic mental representation of the alphabet, then the basis for this judgment is clear: that grammar is best which best approximates to the system that people have in their heads. To show how psychological evidence bears on this question, two sophisticated "linguistic" analyses of the alphabet are examined; the conclusion is drawn that the evidence points toward another analysis.

*I have learned that a good question is greater than the most brilliant answer. Louis I. Kahn*

### 1. Introduction<sup>1</sup>

1.1. The proper characterization of the alphabet is the one that tells us what we want to know. What is that? Put simply, we want to know why it contains the symbols it does instead of some other symbols. Unless, of course, it is merely a congeries of arbitrary and unrelated characters. But if it were, any new arbitrary and unrelated character would be as suitable an addition to the alphabet

1. Part II of this series of papers will present a new characterization of the alphabet in terms of an iconic grammar employing distinctive-feature matrices and generative rules. The distinctive features—unlike Gibson et al.'s—are not chosen for their putative individual psychological reality; rather they are chosen to operate within an over-all system (or "grammar") whose generated *products* are designed to accommodate, and explain, a diversity of psychological findings. The products of this system are, more than letters, letters-cum-analyses: that is, entities structured at a variety of interconnected levels. Among those levels are distinctive ones having correlation with such familiar terms as "discrimination,"

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as any other; and this is patently false. The symbol“  $\exists$  ” is much less acceptable an addition than, say, “  $\wedge$  ”, as the Emperor Claudius discovered.<sup>2</sup> The alphabet cannot be a mere congeries because we, its users, clearly have an idea of “relative suitability,” or “relative wellformedness,” or in other words an idea of to what degree a proposed new letter has in common with the old ones the attributes they have in common with each other. So the alphabet must be a set of characters with rather marked homogeneities, irrespective of how conscious of those homogeneities we might be. Identifying these homogeneities is obviously a first step towards determining why the present letters, and apparently any new letters, must have those features. Given a correct statement of the common features and a correct statement of how far their differences may range, obviously we would be in a position to derive the full set of wellformed letters from the underlying “rules” which determine their eligibility as members of that set. In short, in the familiar sense we would be in a position to present a “generative grammar” for the full set of wellformed letters, where “generative grammar” is used in the sense laid down by N. Chomsky (1957, 1962). Since 1966 the discipline which aims at constructing grammars for pictorial “languages” has had a name, “iconics”; what we are proposing, then, is an iconic study of the alphabet. (On the risks of the linguistic analogy see [Hymes 1964], [Jakobson 1967], and [Minsky 1968].)

“(motor) production,” and so on. To anticipate, these distinctive features are not strokes, but abstract properties of vectors.

Part III will present a number of remaining issues and will tie off some loose ends. In particular, Part III will take up the question of whether or not it is after all legitimate to postulate a single system underlying the several aspects of human performance (ranging from cognitive apprehension through slips of the pen) of the present-day Western alphabets. At this point evidence from iconics will be drawn upon to inform a discussion of the general issue of “competence” and “performance.” A broader discussion of iconics will conclude.

2. That is, Claudius’ “digamma inversum” is less acceptable, for /v/ or any other sound, than “V inversum” would have been. Cf. Diringier (1968, Vol. I, p. 421) and Jensen (1969, p. 524). Eventually, of course, “V” spawned two other letters, “U” and “W,” to “mean” distinctive sounds formerly or variously meant by “V.” Curiously, “V” itself is in turn a degenerate form of primitive “F,” the digamma whose inversum failed so signally (Jeffrey 1961, p. 35).

So far, in the interests of simplicity, we have used the phrase “the alphabet” as if there were only one, and to a lesser degree the phrase “the grammar” in the same way. But there are many different alphabets, of course, just as there are many languages, and there is no more a priori reason to expect one grammar to specify two alphabets than there is to expect one grammar to specify two languages like, say, French and Spanish or French and Vulgar Latin. In appearance, the minuscule Roman alphabet is as different from the majuscule Roman as the Greek or Cyrillic majuscules are; what the grammatical relationship amongst these alphabets might be remains to be determined.

More seriously, though, we have not yet constrained our requirements on the grammar of “the alphabet” to the point where, for a given alphabet, just one grammar would be possible: or just one grammar picked as best. Accommodating noted homogeneities is an insufficient constraint because the rules of stating them could take innumerable different forms: as see the competing solutions examined below. How to choose among them? The answer can be inferred from the preceding paragraphs, and is in its broadest statement almost self-evident: if we are trying to describe alphabets in terms of homogeneities tacitly “known” to the alphabet’s users, clearly the “best” representation of those homogeneities is the one that most closely corresponds to the representation that those users in some sense have in their heads. So, what the preceding two paragraphs add up to is this: there is no correct or adequate treatment of the alphabet that is typographic or epigraphic or paleographic or whatever unless that treatment takes into account what contribution our mind’s apprehension of the alphabet makes to the alphabet’s form; or what in some sense we “know” about the alphabet’s characteristics. Knowing what conditioned ancient Greek alphabetic changes is obviously part and parcel of knowing what occasions our or the Greeks’ acceptance of additions to the alphabet and what conditions variations in the forms of letters. This means that iconics is, among other things, a psychological study. Iconics must lead towards, and at some level confront, the cognitive and visual organization imposed on the alphabet by those who learn, know, and use it.<sup>3</sup> (This point will perhaps be obvious to psychologists or

[(Brown 1964), (Romney and D'Andrade 1964), (Colby 1975)] anthropologists; less so, until recently, perhaps, to students of graphics.)

Now, the notion that iconics is in part a cognitive study cannot have the same implication it would have had five years ago. Then, in linguistics and in the studies (like iconics) historically derived from linguistics, the basic implication was taken to be that a discipline could lay claim to pursuing "cognitive" researches if it achieved a high level of correspondence to fact while adhering to certain principles of economy which bore some indirect cognitive freight. The "facts" to be accounted for went well beyond the essentially adventitious data attested by usage, so that the languages that linguistics hoped to explain were infinite sets of sentences; and the sentences in turn were taken to be associated pairings of syntactic derivations and semantic readings. The principles of economy boiled down to a specific version of the scientific notion of parsimony: in the specific version, two grammars of equal power to account for a given language were to be graded by how many symbols each had (on a component-by-component

3. Although psychologically-oriented disciplines other than psychology itself tend to use "cognitive" to cover "psychological," this usage is permissible only because "cognitive anthropology" and latterly "cognitive linguistics" deal almost entirely with phenomena that psychologists themselves would largely term, as distinguished from "perceptual," "cognitive." I have probably over-used the term "cognitive" in the pages which follow; but I trust no harm has been done since when what is under discussion is clearly perceptual (in our case, "visual"), I believe the appropriate reminders are registered. Lest there be one or two cases of residual ambiguity, though, let me phrase informal definitions of "visual" vs. "cognitive" in terms of how one might "know" or "mentally apprehend" the letter "B": what one does is "visual" insofar as apprehension is atomic ("straight line"; "curved line"; "closed cusp"; perhaps "symmetrical") and/or traceable ultimately to cell-specific functions of the sort discussed by Hubel and Wiesel (1965); what one does is "cognitive" insofar as apprehension is structural or employs rules (e.g., "a 'B' has a staff flying two closed cusps, and is one of a class of similar letters . . ."). The purely visual association between "B" and "b" is about the same as that between "B" and "p"; that "B" is paired with "b" and not "p" is therefore, in a weak sense, "cognitive." The distinguishing factor is not whether or not there is a visual signal (certainly "p" is visually different from "b"), but whether or not the event in question (the pairing "B"/"b") is *predictable* from just that visual signal (predictable by, say, the proverbial Martian). As is plain, the "visual"/"cognitive"/"motor" distinctions being used here are rather informal terms; though they will be toughened up somewhat in Part III.

basis), with the sparer the winner. Naturally no one thought that pursuing a cognitive account, in the sense just sketched, meant that such an account would be necessarily achieved; but the consensus appears to have been that the product of such a pursuit would not be very wide of the mark, needing perhaps only last-minute tinkering to bring it into accord with refractory psychological findings. More recently, however, beginning about 1970, this view has fallen under a cloud. It has begun to appear that linguistics, hence iconics, might be well-advised to consider psychological evidence throughout its investigations and at every stage in the construction of its scientific accounts. Briefly, it seems that, as judged by the “number-of-symbols-per-grammar criterion,” people do not always construct so “economical” a cognitive account of what they learn as would be possible in some idealized case (Watt 1974). (More correctly, their constructed account is partly “economical” by a criterion other than the one that minimizes the size of the grammar at the expense of increasing the complexity of the sentential derivations that constitute the language.) In sum, then, our earlier remark that iconics must clearly be a cognitive study has a rather more direct and more solid implication than it would have had a short time ago: that is, that we must take psychological data into account if we are to hope to achieve an adequate characterization of the alphabet. The “marked homogeneities” we took notice of earlier, the attributes that determine relative suitability for inclusion in our present alphabet—these, then, should be studied with respect to what psychological evidence we can gather, from whatever quarter.

Those quarters are three:

- (1) Experimental evidence, much of it gathered by perceptual or motor psychologists having no direct interest in iconics;
- (2) Ontogenetic evidence (evidence from studies of how children master alphabets and other iconic systems);
- (3) Historical evidence (the records of past and present evolutionary changes and “mistakes”).

Rather than conduct the discussion in generalities, let us examine specific instances of the sort of evidence that iconics must confront. Under (1), then, there is experimental evidence that subjects trying to identify letters flashed at them more easily con-

fuse "M" with "N" than "K" with "Y" (Gibson et al., 1963), and so clearly an iconic account attempting to jibe with this evidence must at some level describe the letters in question so that the first pair of letters shares proportionately more attributes than the second pair. Again under (1), there is evidence (Jonides and Gleitman 1972) that subjects can more easily pick a given letter from among numerals than from among other letters, and so an adequate account must tell us, presumably, why other letters form a less distinctive background for a particular letter than numerals do. Still again under (1), there is evidence (Huttenlocher 1967; Zusne 1970) that subjects (children) have greater difficulty in distinguishing left-right mirror reversals of letters than in distinguishing top-bottom mirror reversals, as long as presentation is horizontal as in a line of print; this finding must also be accommodated.

Under (2), there is developmental evidence (Watt and Jacobs 1975) that children typically master "N," the pair "S" and "Z," and "J" last, of the majuscules; and any adequate iconic account of the alphabet must explain this, clearly. Again under (2) it seems that many children get "S" backwards but "Z" correct or "Z" backwards but "S" correct, and this must be accommodated. Still again under (2), it seems that children after having mastered the majuscules have them all correct, but then after mastering the minuscules and/or the cursives start making "N" backwards on occasion, a habit that quite a few carry into adulthood; and this must be explained (and the explanation is not quite so simple as it might seem).

Passing to (3), there is historical evidence that "T" evolved into "C" (Watt 1973, based on Jeffery 1961), an evolution which must be accounted for by a correct notion of iconic evolution. Again under (3), history shows us that the lower-case or minuscule letters developed fairly simply from the upper-case or majuscule letters (Mallon 1952), in large part due to the interposition of "motor" (hand-movement) factors; and any account of the alphabet that could not square with this evolution should obviously, other things being equal, be disfavored. And lastly under (3), in boustrophedon Greek letters like "B", but not "S", once varied with whether the lines they occurred in were written

(and read) from left to right or from right to left; and this “right-tending/left-tending” bias must obviously be accounted for.

It may still seem a little inconcinuous that evidence of the sort cited should be claimed to bear on the “simple” problem of characterizing the alphabets; but in each case a little reflection will show, I think, that the claim is, rather than far-fetched, if anything too modest. To nudge these reflections in the desired direction, perhaps I might remind the reader that, insofar as he concedes that the only characterization of the alphabets that holds genuine interest is the one that somehow matches the one we have in our heads, and insofar as he concedes inapplicability of any a priori criterion for selecting that characterization, to that extent he ought to welcome any evidence of the impress left on alphabets by the minds (and eyes and contrastively hands) of its users. On this reasoning children’s reversing “J” and the Greeks’ failure to reverse “S” and children’s confusing “S” and “Z” and the effect (as in boustrophedon) on letter-orientation of line-orientation—surely all these sorts of evidence must seem, not only less arcane, but positively germane. I will not belabor the point here, where in any case citation of these kinds of evidence largely serves a negative purpose; but we will resume the discussion in Part III of this series.

Taking a somewhat different tack, we might informally judge a given grammar in terms of breadth (how much it accounts for) and depth (how deep it goes). The two are related, since if only a narrow scope of the language is taken into view the treatment, blind to the requirement that all possible items of the language be accounted for, will necessarily be relatively shallow. (We have to qualify this statement by noting that a grammar of narrow scope [say, the 26 letters of the present-day alphabet instead of the extended set of the wellformed *possible* letters] might nevertheless be judged less shallow if it were partly responsive to psychological criteria of the sort mentioned above. We will return to this point when discussing Gibson et al.)

Continuing this line of attack one more step, Chomsky once upon a time (1965) defined three levels of adequacy relative to which the achievement of a grammar for a language could be judged; these levels, deliberately intermixing “breadth” and

“depth” of analysis, serve as part of the background of modern (generative) linguistics, and I would argue should serve the same function for iconics. The three levels of adequacy are (1) observational, (2) descriptive, and (3) explanatory. The lowest level, the observational, is both narrowest and (therefore) shallowest: it is achieved by an analyst who merely accounts for the data attested by some corpus or set of corpora, a compact representation of the data being the least adequate account. (For a finite list like the alphabetic letters, a mere list would therefore be the minimum adequate account.) A somewhat more revealing observational analysis might break down the elements of its corpus into “distinctive features,” as seen below; at a deeper level, those features or the analysis in general might have some psychological warrant. The next level of adequacy defined by Chomsky, the descriptive, is attained by an account which characterizes the entire set of well-formed elements of the language in question, thus defining the notion, “wellformed element of language *L*.” An analysis at this “broader” level could be “deepened” by squaring it with psychological evidence, thus becoming “cognitively-descriptive” (Watt 1974). (Perhaps the parallel term “perceptually-descriptive” might also prove useful, as see the discussions of Gibson et al.’s work below.) The highest level of adequacy, the “explanatory,” is attained by a grammar constructed within a theory which selects that grammar over all others of descriptive adequacy by appeal to higher principles (e.g., of economy) which, in turn, might guarantee a priori psychological accuracy. This highest level, given the low probability of attaining it in the foreseeable future, corresponds in linguistics to the Grail.

Finally, we can relate these standards of adequacy to another set of distinctions, one split basically along the lines of “discrimination” vs. “production” (or “recognition” vs. “composition”). Clearly, to reprise, an analysis which aims only at discriminating among (say) the 26 letters of the majuscule alphabet, and so which will be “narrow” almost by definition, will be able to achieve no more than observational adequacy; how “deep” such an analysis will be will depend on considerations like those cited just above. The critical factor is the nature of the discrimination task as ordinarily conceived: that task is taken as being met if each ele-

ment whose recognition is desired is so described that it is distinguished from all other such elements (to continue our example, if each majuscule is distinguishable from the other 25). There is no need to distinguish, though, each element from anything *outside* the set of elements whose recognition is sought (no need to distinguish “A” from “4” or from a map of downtown Pittsburgh, for example). The possibility of maintaining so narrow a compass is lost, of course, when we pass from discrimination to composition, since to compose (produce) an “A” one must know, not only how it differs from “B” and the rest, but also how it differs from everything else. Thus passage to a composition task automatically raises one’s sights: to greater “breadth”; to “descriptive” adequacy; and possibly to greater “depth.” As we will see below, it is an interesting question whether or not an analysis built as a discriminational account can be *extended to* (properly included in) a compositional account.

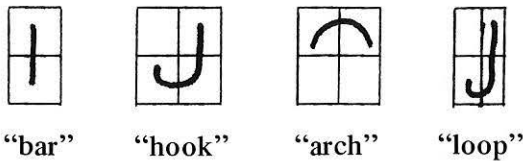
These three interdependent standards of measurement—“breadth” vs. “depth,” Chomsky’s three levels of adequacy, and “discrimination” vs. “composition”—will now be brought to earth in the context of a discussion, taken to some detail, of two existent iconic analyses of alphabetic characters; this discussion will occupy most of the remainder of the paper. Both analyses date from the 1960’s; neither was undertaken with a view toward satisfying the three sets of criteria just proposed (though one aimed at some “depth”), and were it not for the fact that we will be using them purely as illustrations of expository points it would be a little unfair to charge them with the shortcomings to be cited shortly. Both are discriminational analyses. Sometimes we will be singling out their shortcomings relative to their own goal of accounting for (or enabling) discrimination; but at other times, and more to our basic point, we will be remarking where these analyses, even if accepted as discriminationally satisfactory, fail to account for compositional facts and/or fail to permit extensibility to a fuller characterization that *would* account for such facts.<sup>4</sup> The discussion will

4. We presuppose that extensibility is desirable, even though an inextensible recognition routine might be more economical than an extensible one. But after all, we are using Eden-Halle and Gibson et al. to illustrate expository points, not to charge them with dereliction of duty.

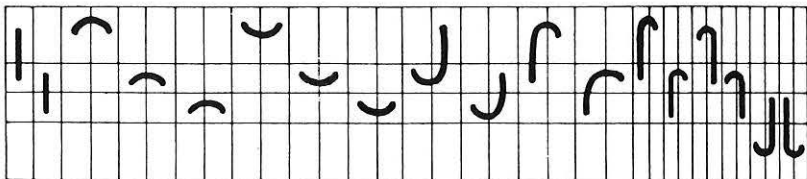
also throw into a lurid light the much-vexed question of whether or not what description of visual “languages” needs is “more rigor”: unless further defined, this statement will be seen to be meaningless, since a successful discriminational analysis is obviously as “rigorous” as could be desired; yet from such an analysis much is lacking.

The two analyses to be considered are both well-known; and comparing them is made easier by their having Jakobson and Halle (1956) as a common ancestor, from which they diverge in complementary ways. They are the Eden-Halle analysis of cursives (Eden 1961, Eden and Halle 1961) and the Gibson et al. analysis of printed majuscules (Gibson et al. 1963, Gibson 1965, Gibson 1969).

Figure 1 (from Eden 1961). (a) A graphic portrayal of the four “distinctive features” of Eden and Halle.



(b) The 18 of Eden and Halle’s “phonemes” that they retain to form letters (“morphemes”).



## 1.2. *Eden-Halle.*

The analysis of English cursive letters by Eden and Halle was designed to produce a system capable in principle of reading handwriting, and it falls within a large class of “pattern-recognition” studies, among which Eden-Halle still stands as an early landmark. (A useful introduction to the so-called “linguistic” approach to pattern-recognition, exemplified by Eden-Halle, is Kirsch [1964]; surveys are Miller and Shaw [1968], Kanal and Chandrasekaran [1972], and Rosenfeld [1973]; a more recent full-length study, comprehensive if oddly uncritical, is Fu [1974]. For a broader view of pattern-recognition in relation to psychological findings as of the mid-1960’s, see Neisser [1967], and cf. Shillman et al. [1974].) Eden and Halle characterize the modern English cursive letters in terms ultimately of four “line-segments” which they explicitly (p. 295, *n.*) identify as analogous to the “distinctive features” of a generative linguistic grammar (e.g., Chomsky and Halle 1968). These four line-segments (“bar,” “hook,” “arch,” and “loop”—v. Figure 1, *a*) are then altered by rotation (their “reflection”) on either horizontal or vertical axes to yield eleven visually different line-segments, of which only nine are retained at the next level. (The issue of visual ambiguity [cf. Baird and Kelly (1974)] is thus neatly and quite properly sidestepped). Those nine are at that level positioned in one of three partially-overlapping “fields” to constitute, finally, the “strokes” from which letters are to be formed. Eden identifies these “strokes” as analogous to “phonemes” (1961, p. 84, *n.* 6). (To minimize confusion, below I will spell the distinctive features as “Bar,” “Hook,” and so on, and the “phonemic” strokes containing or incorporating those features—along with others—as “bar,” “hook,” and so on.) Some of the “strokes” are also discarded before advancing to the next level; the eighteen that are retained are given in Figure 1, *b*. At the next and (more-or-less) last level these strokes are combined sequentially into proto-letters (e.g., those of Figure 2, *a*), Eden’s “morphemes” (*ibid.*). Then by a subsequent “collation rule” (something like a “morpheme structure rule”) the strokes of these proto-letters are adjusted into the recognizable letters of Figure 2, *b*; and by another “collation rule” (a little like a “sandhi rule”) these letters, when placed into sequences to form words, suffer a

final readjustment. An outcome of this process is shown in Figure 2, *c*.

Though designed to be used as a recognition or discrimination device, Eden-Halle is nevertheless a limited generative device, and it can be used to compose rough-and-ready approximations to handwriting, as demonstrated. Since it is compositional capacity that is of greater interest, we will take that aspect of Eden-Halle as our primary focus in considering its shortcomings. (I stress once more that these are for the most part shortcomings which in the “pre-cognitive” days of the early 1960’s were quite invisible.)

The first shortcoming we might note is the most glaring — words composed in terms of the analysis and by use of its cursive letters and “collation rules” are often virtually illegible. Silent confirmation of this suspicion is provided by Figure 2, *c*: the “globe” there presented is so imperspicuous that in (Eden and Halle 1961) it emerged into print, presumably after several publisher’s scrutinies, upside-down. But a more serious point engages still more directly the “observational” vs. “explanatory” issues raised just above: the letters formed by the Eden-Halle system do not, by and large, seem to be compatible with any of the three sorts of psychological evidence (experimental, ontogenetic, historical) cited above.

Historical evidence is slighted because the origins of the cursive letters are in some cases absolutely occluded by their Eden-Halle derivations; for example their minuscule cursive “s” (Figure 2, *d*) is composed of a “hook” plus a “cup,” with the “s”-curvature of the letter, reflecting its derivation from printed “s,” vanishing irrecoverably.<sup>5</sup> Such historical evidence is of more than pedantic interest, since passing to contemporary observation it is certainly possible that modern users, including children, are aware of the connection between printed and cursive “s,” and that this tacit knowledge affects their performances. Nor is this merely a criticism of a particular solution within an Eden-Halle analysis of more general capability; obviously their analysis of “s” could not easily

5. This is the place to retract a statement I have made elsewhere (Watt 1973), based on a too-hasty reading of some old notes, to the effect that the “hook” of the Eden-Halle “s” is the *first* stroke rather than its second.

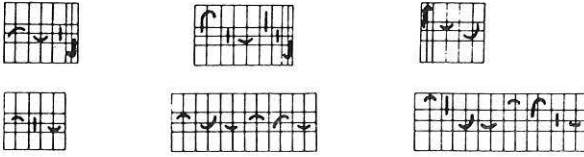
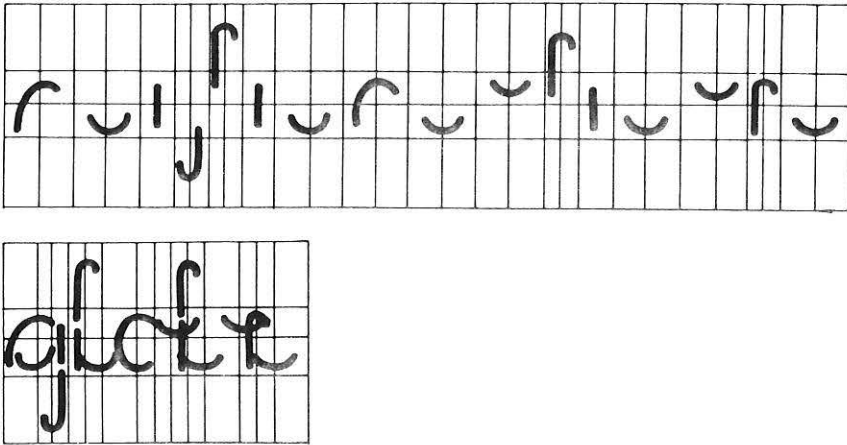


Figure 2 (from Eden 1961). (a) Above: Eden-Halle proto-letters ("morphemes").  
 (b) Below: the "collated" letters corresponding.



(c) The word "globe" as generated by Eden-Halle, first as a sequence of proto-letters and then as a twice-collated "word."



(d) The minuscule letter "s" in terms of its "distinctive features."



be rectified in the direction indicated (a new “Serpent” feature might do the trick), just as their system could not easily dot its “i’s” or cross its “t’s.” (Eden [1961, p. 84, n. 5] observes that “t’s” cross and “i’s” dot are redundant: a remark applicable to discrimination, but scarcely to composition.) On the issue of whether or not the Eden-Halle analysis is compatible with experimental or ontogenetic evidence, we ask whether or not their distinctive features have, or bid fair to have, the psychological implications that such features have been taken to have elsewhere. To begin to answer this question, however, it will be useful first to recast the Eden-Halle analysis into a more accessible form. They say that their solution is in terms of “distinctive features”; but as the reader must have observed himself, this notion fits into Eden-Halle in a way unfamiliar to those used to the linguistic systems from which it was borrowed. Their distinctive features “Bar,” “Hook,” “Arch,” and “Loop,” do eventually occur in the complexes, or bundles, which define the “strokes” (“phonemes”) from which the letters will be formed. But these bundles of “distinctive features” are unusual in that they include elements other than distinctive features: since the features themselves, before they emerge into bundles, have been radically altered by rotation and placement “operations” (not given a linguistic correlate). Since it is not clear why a given stroke is more distinctive for being “Hook” than for having been rotated 180° or for having been visibly lowered, Eden and Halle’s segregating their “distinctive features” from their “operations” does not seem motivated. Thus, since in any case we will want a way of accounting for expected responses to rotation as a minimum discriminator between strokes or letters—hence as a potential “distinctive feature” in the accepted sense—we will adapt Eden-Halle accordingly, introducing four new distinctive features: “Raised,” “Lowered,” “Rotated,” and “Mirrored,” as shown in Figure 3.

We turn now to consider how “deep” Eden-Halle strikes *as a discriminational analysis*. The sorts of psychological evidence we might expect for a mentally internalized “distinctive feature” system like that of Figure 3 have often been discussed (v. Gibson 1969). Two are: (1) if strokes are mentally distinguished from each other by these distinctive features (and by nothing else), it should

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
									~	J		~						
	~		~	J						J		~						
															~	~	J	
BAR		+						+										
HOOK				+			+			+				+				
ARCH	+		+						+			+			+	+		
LOOP					+	+					+		+				+	+
ROTATED	+				+	+	+				+	+	+	+		+		
MIRROR-ED					+						+							+
RAISED								+	+	+	+	+	+	+				
LOWERED															+	+	+	+

Figure 3. Chart of distinctive features for "Strokes" forming letters of the alphabet (adaptation of Eden-Halle).

follow that under difficult viewing conditions their confusability should increase as the proportion of shared features increases (for phonological features, see Brown and Hildum [1956]). And (2), if children are indeed internalizing a Figure 3 matrix, they should first discriminate between strokes having the greatest number of distinctive-feature differences (for phonological features, see Scvachkin, as cited in Tikofsky and McInish 1968, Gibson 1969). But when we ask if the Eden-Halle solution suggests confirmability in terms of such psychological attributes, the answer is no. For example, referring to the chart of Figure 3, the 2nd and 3rd

strokes are distinguished by disagreement on two features, Bar and Arch; but the 2nd and 4th strokes are also distinguished on two features, Bar and Hook; yet obviously the 2nd stroke ("bar") is much closer to, hence expectably more easily confused with, the 4th stroke ("hook") than the 3rd ("arch"). Yet again, notice that the 13th and 14th strokes also differ by two features (Loop and Hook); yet surely the 13th and 14th strokes are much more easily confused. So far we have dealt only with Eden and Halle's original four features, which have the curious characteristic that no two strokes can differ on just one feature (e.g., the "hook" and "arch" must differ on features "Hook" and "Arch" *both*); but our failure to find expectable psychological concomitants extends also into the eight-feature system, for notice that the 1st and 16th strokes differ by one feature (Lowered) and the 1st and 3rd do also (Rotated); yet surely the confusability of these two pairs should not be identical. Turning now to the opposite effect—maximum difference *cum* earliest discrimination—we find the same lack of correlation. To take just one example, the 11th and 7th strokes differ by four features (Hook, Loop, Mirrored, and Raised), while the 2nd and 15th differ by only three (Bar, Arch, and Lowered); yet presumably it is the latter pair that are more easily distinguished, certainly by children; the literature on children's reversals of letters is too univocal for us to think otherwise (v. Watt and Jacobs 1975).<sup>6</sup>

6. Of course "Mirrored" and "Rotated" could be struck from the list of distinctive features, which would aid things; but it is not at all clear what role these two attributes play in Eden-Halle unless they *are* distinctive features.

We might also note again, that Eden-Halle was a pioneering study and that doubtless its authors would change much in it if they redid it. In particular, one might speculate that they might change their original four distinctive features "Bar," "Hook," "Arch," and "Loop" so as to permit a more economical definition of their strokes. For instance, their "Hook" is obviously resolvable into a "Bar" plus a "Rotated Arch," and if the "Arch" could be appropriately reduced, the "Loop" could be similarly constituted. Then "Hook" and "Loop" would be eliminated entirely from the list of distinctive features, being replaced in each case by a sequence of two distinctive-feature complexes "Bar" plus "Arch" or "Bar" plus "Reduced Arch," with or without rotations and/or mirrorings. Other improvements in Eden-Halle could also be envisaged; but *passons*.

Of course, it may not be correct to suppose that “confusions” should uniformly correlate with “distinctive features” of the sort in question—see below for some problems with any such supposition—but on the other hand, the failure of Eden-Halle to correlate is so thoroughgoing as to discourage further attempts, at least from this angle, to invest it with psychological significance. More generally, it can be said that the failure of Eden-Halle to rise above observational adequacy was, rather than an accident, a direct product of their aim of constructing an *analytic* device for recognizing handwritten characters (even though the device takes the form of a generative device). Such an aim is, if realized, destined to produce a paradigm case of Chomsky’s “observational adequacy.” Eden and Halle emphasize this aspect of their work in a number of passages: for instance, in one they straightforwardly admit that letters (like “z”) that have distinctive variants (“**3**” and “**z**”) are simply entered in their lexicon as two separate and unconnected forms (Eden and Halle 1961, p. 290). Such decisions are no hindrance to the achievement of a purely analytic device: but that letter variants are not related to each other is fatal for any theory aspiring to a higher level of adequacy, since at those higher levels contact is made with interconnections: with what the users of the alphabet tacitly “know” about it, insofar as that knowledge determines the alphabet’s forms. Equally telling, on the same score, is the fact that in Eden-Halle there is no systematic connection between majuscule and minuscule counterpart.

As a general conclusion, we might say again that present-day analysts of visible languages, or of pictorial systems, do not in demanding “more rigor” of their analyses demand nearly enough. Eden-Halle is “rigorous” enough to pass into a computer recognition program; but by any sort of explanatory or cognitive criterion it must be judged a fascinating failure.

### 1.3. *Gibson et al.*

Often cited, the work of E. J. Gibson and her collaborators (Gibson et al. 1963, Gibson 1965, Gibson 1969) was aimed directly at the achievement of “psychological adequacy” in the characterization of an alphabet, in this case the simple Roman majuscules. Their distinctive features are attributes, not of strokes as with

Eden-Halle, but of the letters themselves (so that Eden-Halle's "morphemes" are Gibson et al.'s "phonemes"). In intent, their features were not chosen by whether they *can be* used to distinguish letters, but by whether they *are*; thus Gibson et al., though they were not aiming at an account of compositional power, were aiming at a discriminational account having merit as a "perceptually-adequate" account. Their systems of hypothesized distinctive features were tested with subjects to try to ascertain whether or not informants seem actually to use those distinctive features in their visual letter-discriminations. The actual "confusion" test of the hypothesis was, like many another, rather simple, since what it set out to show was only that as letters are more similar when judged by degree of shared hypothesized distinctive features, they are concomitantly more often confused (mistaken for each other) by four-year-olds.<sup>7</sup> However, the distinctive features themselves were not chosen blindly, or to provide the right test correlations: rather each was meant to have the warrant of independent psychological (neurophysiological) evidence.

Let's have a look at this evidence. One distinction between kinds of lines is that between straight and curved; Gibson et al. accept this as a basic distinction on evidence from neurophysiological research with frogs (Maturana, Lettvin, McCulloch, and Pitts 1960). Another set of basic differences, among straight line-segments, distinguishes verticals, horizontals, and various diagonals; these they accept on evidence from work with cats (Hubel and Wiesel 1962). [To interrupt, we see that Gibson et al.'s reasoning ran somewhat as follows: "If animals can be shown to make elementary distinctions between 'X' and 'not-X,' then 'X,' with values plus or minus, is a good candidate for inclusion in our set of distinctive features, if it can be used to discriminate letters." In the cases at hand, one asks of a given letter: "Does it have a straight line?" (i.e., "Is it plus or minus 'Straight-line'?"), and so on, accumulating a description of letters in terms of the distinctive

7. Even if the correspondence between "number of shared features (duly weighted)" and "degree of confusion" had been very close, such a series of experiments could at most have proven that the hypothesized set of features was *compatible with* the evidence.

features hypothesized.<sup>8</sup> NB that with Gibson et al. the “distinctive features” of letters are characteristics which typically apply only to *part* of the letters; thus, “B” is assigned the feature “PLUS Straight-line” because it *contains* a straight line. We return to this point below.] Reference may be made to Figure 4 from this point

8. Granting the validity of the individual features, one might suppose that their effects as discriminators, hence their appearance in discrimination matrices, were free from any further uncertainty; but not so. Batchelder and Narens have recently pointed out (1975) that performing quite straightforward Boolean transformations on a feature matrix—constructing a new matrix whose features consist of pairs of the old matrix’s features joined by logical connectives—can produce a radically different characterization of the items being discriminated; they also point out that the result of such a transformation, however bizarre, is not automatically discountable on objective grounds of “unnaturalness” or whatever. An example will illustrate. Let us for convenience take a small three-feature matrix in which five letters are distinguished—(i), below—and transform it into a new (ii) in which each possible pairing of (i)’s old features appears, connected by the Sheffer stroke (‘|’), in a new feature, so that for two old features ‘ $\alpha$ ’ and ‘ $\beta$ ’, new feature ‘ $\alpha | \beta$ ’ is to be assigned its plus and minus values in (ii) in this way: “MINUS in (ii) if features ‘ $\alpha$ ’ and ‘ $\beta$ ’ are both PLUS in (i), under the same letter; otherwise PLUS”; as follows:

	(i)					(ii)					
FEATURES	C	H	R	A	P	FEATURES	C	H	R	A	P
Curved	+		+		+	Curv   Sym	+	+	+	+	
Symmetric	+	+		+		Sym   Diag	+	+	+		+
Diagonal			+	+		Diag   Curv	+	+		+	+

As we see, the (ii) feature “Curved | Symmetric” is assigned MINUS (blank space) under the letter “C”, because in (i) both “Curved” and “Symmetric” were PLUS under “C”; whereas the same (ii) feature is assigned PLUS under “H” because in (i), under “H,” “Curved” and “Symmetric” were *not* both PLUS.

The transformation (i) into (ii) radically changes the relations among the letters of the matrix, as predicted: for instance, in (i) “R” is more similar to “A” than to “H,” whereas in (ii) this relation is exactly reversed. And notice that, since we did not guard against it, (ii) has lost information, since in (ii) “H” and “P” can no longer be discriminated at all. (And note that (i) is not *recoverable* from (ii).)

The point just made would be less serious did not the “features” derived from rummaging through such sources as Hubel and Wiesel (1965) often appear to be neurophysiologically joined by logical connectives, in that for example a “hyper-complex cell” able to distinguish one “feature” does so only while also distinguishing another.

on (with qualifications to be noted). As to curved lines, Gibson et al. identify as distinctive features “Open” (like “C”) vs. “Closed” (like “B”), basing this decision on data from research on the early development of form discrimination (Gibson et al. 1963). They include a feature of “Intersection” on similar grounds, citing Piaget. Two additional features of “redundancy”—“Cyclic change” and “Symmetry”—are added to the list; the second of these is present in letters which are symmetrical on the horizontal axis (“B”), the vertical axis (“A”), or both (“X”); while the first, a somewhat more arcane attribute, is said to be present in letters showing parallelism, though it seems to be found in “E” and “H” but not in “Z.” In any case, “Cyclic change” is claimed to be based on some stabilized retinal image research in which parallels act as units in appearing and disappearing (Pritchard, Heron, and Hebb 1960). Lastly, “Vertical terminates” (as in “H” but not “E”) and “Horizontal terminates (as in “F” but not “H”) are added as features, on the ground that termination (“discontinuity” in their terminology) has been shown to fire certain cortical cells (Hubel and Wiesel 1965). Note that all of these features—hence presumably any system based on them—are “visual” rather than “cognitive.”

We must note in passing that the system just described (and presented in Figure 4) is not precisely Gibson et al.’s system. They do not enter “Straight” or “Curved” as distinctive features in their list, perhaps because they are redundant given the fact that in their account all “Straight” letters, and only these, are “Horizontal,” “Vertical,” or “Diagonal.” Again, Gibson et al. enter two distinctive features to cover the “Open” value of the “Open/Closed” discrimination for “Curved” letters; one of these features is used just to distinguish “U” from “C,” and since identifying the presence in “U” of “Straight” lines will do this just as well, I have jettisoned this part of their analysis. Lastly, the letters in Figure 4 are not in any case exactly as Gibson presents them (1969, p. 88), even where the distinctive features are the same, for that presentation appears to contain a number of typographical errors, which I have silently corrected (while doubtless adding some new ones).<sup>9</sup>

9. Perhaps I should also mention that I have retained a couple of feature-attributions because, while they might not seem to fit the letter concerned as a

	A	E	F	H	I	L	T	K	M	N	V	W	X	Y	Z	B	C	D	G	J	O	P	R	Q	S	U
CURVED																+	+	+	+	+	+	+	+	+	+	+
STRAIGHT	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+	+			+
HORIZONTAL	+	+	+	+		+	+								+				+							
VERTICAL		+	+	+	+	+	+	+	+	+				+		+		+		+		+	+			+
NE DIAGONAL	+							+	+		+	+	+	+	+											
SE DIAGONAL	+							+	+	+	+	+	+	+									+	+		
CLOSED/OPEN																+		+			+	+	+	+		
INTER- SECTION	+	+	+	+			+	+					+			+						+	+	+		
CYCLIC		+						+				+				+									+	
SYMMETRY	+	+		+	+		+	+	+		+	+	+	+		+	+	+			+					+
VERT. TERMINATES	+		+	+	+	+	+	+	+	+	+	+	+	+						+		+	+			+
HORIZ. TERMINATES		+	+			+	+								+		+		+						+	

Figure 4. Chart of distinctive features for letters of the alphabet (after Gibson 1969).

The set of features is a little altered from Gibson's, though not much (see discussion in Section 1.3, above). I have basically used Gibson's characterization of the letters even where I found it dubious. I have added "Horizontal Terminates" for "C," "G," and "S"; and as mentioned above, I have redone "U" altogether: *v. n.* 8. The description ignores serifs.

	A	V	F	Ɔ	H	4	T	⊕	K	IX		D	⊖	∞	8	9
CURVED												+	+	+	+	+
STRAIGHT	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
HORIZONTAL	+	+	+	+	+	+	+	+								
VERTICAL			+	+	+	+	+	+	+	+		+	+	+	+	+
NE DIAG.	+	+							+	+						
SE DIAG.	+	+							+	+						
CLOSED/OPEN												+	+	+	+	+
INTER-SECTION	+	+	+	+	+	+	+	+	+	+						
CYCLIC																
SYMMETRY	+	+			+	+	+	+	+	+		+	+	+	+	+
VERT. TERM.	+	+	+	+	+	+	+	+	+	+						
HORIZ. TERM.			+	+			+	+								

Figure 5. Letters and anti-letters characterized after Gibson.

Most of the anti-letters—each indistinguishable by the Gibsonian characterization from the next true letter to its left—would occur to anyone looking critically at Gibson et al. The first did occur to Restle [1975, p. 196], with several others whose claimed indistinguishability, however, is false. E.g., Restle's **F**, claimed to be Gibson-equivalent to F, is symmetrical where F is not; Restle's **4**, claimed to be Gibson-equivalent to H, is not symmetrical (by the Gibsonian criterion) where H is; Restle's **≠**, also claimed (p. 197) to be Gibson-equivalent to H, contains a diagonal where H does not; and so on.

I should note that perhaps some of my anti-letters—with their genuine counterparts—should be +Cyclic. The last 5 figures are all of them Gibson-equivalent.

In any event, the intended predictive thrust of Figure 4's chart of distinctive features is obvious enough: namely, that for any two letters the higher the percentage of their features they have in common (hence putatively the more similar they are), the more likely those letters are to be confused.<sup>10</sup> To test this, Gibson et al. ran a "confusion experiment" and derived correlations between the resulting confusion matrix and their distinctive-feature matrix. (It bears mention that they were therefore testing "perceptual" features by an experiment in which "cognitive" judgments might skew the results; but we must defer further discussion of this point until Part III, where the requisite range of phenomena and hypotheses can be brought to play. See, in the meantime, Restle's discussion (1975, pp. 197-200) of "cognitive" processors like "EPAM" and "Pandemonium," which can overlies perceptual features in such a way as to make feature/confusion-matrix prediction a less simple matter.) Since the features chosen and their letter-descriptions do have a measure of intuitive appeal, it is no surprise that these correlations proved promising; at least the con-

general rule, they do fit the form of the letter used by Gibson et al. For instance, their "K" is correctly ascribed the "Intersection" feature because the form they used in their experiments was: **K** (Gibson et al. 1963). For another instance, their use of their "Vertical Terminates" and "Horizontal Terminates" features does not apply to standard fonts because of the presence in the latter of serifs, which generally (though not always [Hochuli 1973]) replace a "Vertical Terminates" with a "Horizontal Terminates" and vice versa.

However, in other cases I have corrected what I took to be simple errors. As one example, surely if both "F" and "T" are assigned the feature "Vertical Terminates" then "L" ought to be assigned that feature too? Yet in Gibson (1965) it is not (a mistake lovingly preserved in Gibson [1969]). Several other dubious entries also concern "Vertical Terminates" and/or "Horizontal Terminates"—for instance, why should "A" be assigned "Vertical Terminates" when "X" is not?—but there are errors elsewhere as well, besides decisional disparities which it is hard to account for. For instance, how can "A" be assigned "Vertical Terminates" in the first place, when it has not been assigned "Vertical"?

10. It must, of course, be percentage of shared features ( $\frac{\text{intersection}}{\text{union}}$ ) that is decisive, rather than *number* of shared features; for if the latter measure were used, then complex letters sharing a few features could be judged as similar to each other as simple letters sharing almost all of their features. (The reader is not invited to test how well this statement holds up in the Gibson et al. matrix of Figure 4, however; the statement applies only to the *ideal* case.)

fusion matrix correlated better with the feature matrix than chance, and better than the results of a Ramo-Wooldrige letter-overlap technique. However, there were still many cases where something was obviously amiss, as Gibson et al. concede; and clearly their line of attack would have to undergo rather extensive improvements to justify thinking that its constituent distinctive features have genuine warrant of psychological reality. We now take up these and other shortcomings and limitations.

One limitation of the Gibson et al. approach is simply a limitation of any orthodox discriminational analysis (however "deep," and whether "visual" or "cognitive"). It can be encapsulated as follows: the Gibsonian distinctive features that describe **P** and **L** are the same ones that describe **q** and **J**. The reader can easily ascertain that this is so from a glance at Figure 5, where several letters and non-letters have been assigned their obvious Gibsonian analyses. For Gibson et al. the addition of features to distinguish **q** from **P** would have been superfluous and unallowable, since **q** is not a letter and so need not be discriminated. (A similar point is made by Restle [1975, pp. 175f.].) This means that when the reader discriminates between **P** and **q**, as may one presume he just did, he is performing a feat beyond the ability of the Gibsonian description to describe. Since this discrimination must be made by children learning the alphabet (at first many children are indifferent to whether "P" faces right or left), the issue is apposite; and it is certainly critical with regard to the facts of *composition*. Of course the new feature "Right-Facing" could be added to the complement of features (with "MINUS Right-Facing" meaning "left-facing"), and indeed such an addition might begin to remove some of the anomalies which, in the Gibson et al. confusion matrix, follow in the trail of "J," the majuscule alphabet's one left-facing letter. However, this addition cures but one problem ("I" would still be indistinguishable from "L," for example): the indicated panacea lies elsewhere, as we will see shortly.<sup>11</sup>

11. These limitations apply whether "distinctive features" are extracted as in Gibson et al., or whether, as in Rumelhart and Siple (unpublished) the "Features" are line-segments used essentially in template-matching. Incidentally, the success of the latter analysis in explaining away the Reicher-Wheeler Paradox,

is, if generalizable to reading discrimination at large, puzzling, since any template-matching analysis will be hard put to account for the apparent fact that on first exposure people instructed to "read backwards" can more easily read (a) than (b):

- (a) SKADON ETHA 2KAD2  
(b) SKADON ETHA SKADOS

Line (a) is printed and read retrograde and each letter is printed and read retrograde; line (b) is printed and read retrograde but each letter is printed and read oriented normally. Thus, line (a) is "Mirrored" in Kolars' terminology (Kolars 1968, 1969; Kolars and Perkins 1969, 1975), while counter-scan line (b) is "reversed Mirrored."

I introduce this terminology for a purpose, since in the work of Kolars and his collaborators it does not seem that "M" lines *are* more easily read than "rM" lines, by the naive (unpracticed) person: though after about three to five hours' practice in reading these and other distortions those same people apparently do find "M" lines easier (Kolars 1968). (In a subsequent experiment of admirable ingenuity Kolars and Perkins [1975] found that training subjects in one sort of distortion differentially affected their performances in reading others; roughly, training them in a distortion in which [as in "M"] letters share the orientation of their lines [facing rightwards if the line scans rightwards] or in which [again as in "M"] letters are retrograde [backwards], makes reading "M" easier than reading "rM" *unless* the training distortion can be read "normally" by mentally standing it [or oneself] upside-down, or unless it trains one in reading text in which the letters are oriented "counter-scan" and/or in reading text in which its backwards letters are also upside-down and so [probably] fail to ease the reading of the backwards letters of "M." [Thus, in Kolars' terminology, "rN" and "I" raise "M" over "rM"—as of course does "M" itself—while "R," "rR," and "rI," with "rM" itself, raise or leave "rM" over "M"].)

The critical factor that prevents Kolars et al.'s researches from impinging directly on the "M" easier than "rM" claim made above is this: those researches deal with lower-case letters, while our claim applies to upper-case letters only, as only the latter bear on Rumelhart's results. The difference is not trivial, since the upper-case letters have as a set the property that no one of them is distinguished from another only by a difference in orientation (one facing leftwards, the other rightwards), whereas of course amongst the lower-case letters "p" and "q" differ only in orientation ("Mind your *p*'s and *q*'s"), as do "b" and "d." This means that with upper-case letters, but not with lower-case, orientation-invariant properties can be relied on for identification; which in turn means that consistency of letter-orientation and line-scan, as in normal text and in "M" texts, can be more important than whether or not the individual letters, as in "M," are backwards.

Harcum and Filion (1963) did use majuscules, but it is very hard to interpret their results. Briefly, they report two experiments in which subjects were required to reproduce, from tachistoscopically-presented displays of eight-letter words or "nonsense words," which letters they had seen and in which orientation (normal or retrograde); in the first experiment it seems that "M" sequences are less error-provoking in the right half of these eight-letter sequences than are the "rM"

Other limitations are more the product of Gibson et al.'s particular analysis; and these militate against the analysis *on purely discriminational grounds*. For instance, a glance at Figure 4 will show that "C," "O," and "S" have three features each, and "G," four; and that "C" shares with "G" two of the five features they have jointly; with "O," two of the four they have jointly; and with "S," again two of four. Since the basis for comparison is percentage of shared features, clearly the prediction is that "C" should be confused with "O" and "S" more often than with "G." But this is counter-intuitive (as Gibson et al.'s own confusion matrix II bears out: "C" was confused with "G" as often as "M" was with "N"; while "C" was [implausibly] no more confused with "O" or "S" than it was with "H"). How can this particular prediction have gone so far awry? The answer is that in terms of Gibsonian features "C" must be described as "Symmetric," which "G" of course is not, and "G" must consume two additional features, "Horizontal" and "Straight," just to describe "G's" little tail. What is wanted, obviously, is a description of "G" *that will include that of "C."* But this brings us hard up against a cardinal facet of the Gibson et al. analysis: description of parts of letters is impossible. This statement stands despite an extremely curious circumstance

sequences (Harcum and Filion's "DRW" and "SRW" respectively), but more so in the left half, where the "fixation point" was in the middle. However a closely similar second experiment seems to unseat this result; and, since misreproducing *either* a letter *or* its orientation was counted as an "error" it would be hard to interpret these results in any case.

That "M" is easier than "rM" is an informal finding based on asking some forty people of every description which they thought was easier to read, and getting a unanimous response; the experiments necessary to test this conjecture are shortly to be run at the University of California, Irvine. Meanwhile perhaps Kolers' results might actually be taken to be corroboratory, in the following sense: if after about three hours' practice with reversed letters subjects find "M" easier than "rM," "M" must be intrinsically easier than "rM" after all, except for the unfamiliarity of the retrograde minuscules. What did Kolers' subjects learn? If they just learned 26 new retrograde letter-templates or just learned how to reverse their original 26 templates, his result is something of an anomaly, since if template-matching were literally all that was involved the original (normal) 26 letter-templates should serve just as well, always, backwards and forwards. Thus, one is apparently constrained, at the very least, to adopt the view that "templates" are easier to match if their letters match the direction of scan. But what sort of templates are those?

of their description, remarked above: namely, that their distinctive features seldom apply to all of the letter they are ascribed to, applying rather to some fragment. Thus, for instance, “B” is assigned the feature “Straight” and the feature “Curved,” but of course “B” is not as a whole simultaneously straight and curved, nor is any segment of “B.” This circumstance is in fact a serious shortcoming, rather than an avenue along which the troubles with “C” and “G” could be resolved, because though the Gibsonian features mainly apply only to parts of letters, Gibson et al. provide, and are able to provide, no way of specifying *where are located* the parts that give the letters these distinctive features. Which (again) is why “I” and “L” would have to be given identical descriptions in the Gibson analysis.

What this means is that Gibson et al.’s expressed hope of improving their system by weighting some features (Gibson 1969, p. 90) will be unavailing, since in this instance what needs fixing is not the features’ weights but their domains. Thus, suppose in order to bring “C” and “G” closer together we assigned a lower weight to the “Symmetric” feature, found in “C.” This would be disastrous elsewhere. For instance, “F” and “T” disagree only on this one feature “Symmetric,” otherwise sharing six of their seven features; while comparatively “F” and “E” are already too far apart, sharing but five of eight. Reducing the weight of “Symmetric” would only draw “F” and “T” still closer together, so that the problem with “C” and “G” would simply have been sloughed off onto two other letters. Of course the system could acknowledge the diminutiveness of “G’s” tail by adding a “Halved” feature to “G’s” description,<sup>12</sup> which new feature could have the attribute of halving the values of all features ascribed to any segment to which “Halved” were assigned, thus reducing “G’s” distance from “C” from the other direction—except that, again, the Gibson et al. analysis *cannot recognize* contained segments in order to attribute features to them. No half-way measure will suffice (for a still more modest measure see Geyer and DeWald

12. Such a “Halved” feature would have the sort of psychological warrant sought by Gibson et al., as see Hubel and Wiesel (1962).

[1973] and, from a slightly different perspective, Figure 6, below); the kind of rectification suggested by Gibson is foredoomed.

Nor is this all. So far we have been examining shortcomings discernible just in comparing the Gibson feature matrix with their own confusion matrix or with useful addenda like that suggested by the reader's being able to distinguish **Q** from **P**. That is, to this point we have stuck to the discriminational evidence. When we turn to the compositional (and more "cognitive") evidence, the points made above become even stronger. Some of this evidence has been cited above (and see Watt 1975, Watt and Jacobs 1975) and so I will only summarize it here. Briefly, then, the Gibson feature-matrix seems unable to account for the clear fact that children learning to print the alphabet often pair "S" and "Z," making one backwards so as to be closer to the other (the Gibson et al. confusion matrix does not predict this fact either); or for the

Figure 6. Chart of distinctive features for several letters of the alphabet (combining the least desirable aspects of Eden-Halle and Gibson et al.).

Instead of merely recording PLUS and MINUS values, numerical values have been registered, indicating the number of strokes or segments which the feature in question describes. For the Roman majuscules, the range of such numbers is from 1 to 4.

	A	B	C	E	K	L	N	U	X	Z	Q	P	R
STAFF	3	1		4	3	2	3	2	2	3		1	1
APERTURE											1		
TAIL											1		1
BREAST		2	1					1				1	1
HALVED	1	2		3	2	1		3		2		1	1
ROTATED 45°	1				1				1	1			
ROTATED 90°				3		1		1		2			
ROTATED 135°	1				1		1		1				
ROTATED 180°			1										

fact that many children continue to reverse “J” after they have ceased to reverse all the other letters; or for the fact that when writing the alphabet children often make “S” fifty per cent taller than all the letters preceding. Historically, the Gibson analysis can account for very little of the abundant epigraphic and paleographic evidence of the evolution of the majuscules: for instance, it seems to have no way at all of predicting or even accommodating the composition-derived facts that “**I**” evolved into “**Z**,” or that “**Γ**” evolved into “**<**,” or that “**ξ**” evolved into “**S**,” or that in boustrophedon (in which odd-numbered lines were written from right to left) all right-left asymmetric letters were always reversed except that “**S**” was often exempted and “**N**” was often gotten backwards (Watt 1975). And as to casual empirical (contemporary historical) knowledge, the Gibson analysis has no way of predicting or accommodating the plain fact that many adults, in printing their majuscules in “OPEN” signs for gas-stations and the like, reverse “**N**.” (That they commonly reverse *only* “**N**” is not predictable from the printed majuscules alone [Watt 1975].)

The Gibson et al. analysis, based on “visual” (mostly perceptual) features and aiming at an account of “visual” discriminations, cannot handle the demands we have outlined; those demands, however, add to “visual” factors “cognitive” and even “motor” factors. Taken thus, our criticism—though perhaps elucidative—is in a way unfair. It is fairer, though, if we raise our sights a little and ask if, whatever its faults as it stands, the Gibsonian analysis can be *incorporated* (properly included) within a broader and deeper account which, containing cognitive explanations and the necessary references to “motor” aspects, will make up the deficiencies noted. If so, then Gibson et al.’s analysis, after some tinkering, would suffice; if not, not. Alas, the answer appears to be in the negative. The inability to attribute “visual” features correctly to internal letter-components becomes at any cognitive level an inability to attribute “cognitive” features correctly to internal letter-components; it must to a strict Gibsonian analysis remain forever a mystery why children typically get “**N**’s” backwards well after they have gotten “**E**’s” made correctly: for nothing in a “feature” analysis of whole letters even hints at such events. In fine, no strict Gibsonian analysis—even under the

Geyer-DeWald recension (1973)—is properly-includible in a correct broader account; the most permanent accomplishment of the work of Gibson et al. is likely to be its enduring status as the pioneering study in its field.

But it is not our purpose to arraign Gibson et al. They chose a limited goal, that of representing the minimal discriminations necessary for four-year-olds to distinguish the existent majuscules. Theirs was therefore a goal within “observational” adequacy, despite their reliance on psychological warrant in choosing their distinctive features, and certainly that level of adequacy was achieved. Owing to the psychological warrant of their features, they moved a step towards descriptive adequacy, even towards “*perceptually*-descriptive” adequacy; but as we have seen in their inability to distinguish  $\mathfrak{Q}$  from  $\mathfrak{P}$ , full descriptive adequacy was assuredly not achieved.

#### 1.4. *Comparison of Eden-Halle and Gibson et al.; Summary.*

Eden and Halle used distinctive features to describe strokes (their “phonemes”) which were in turn combined into letters (their “morphemes”). Gibson et al. used distinctive features to describe letters directly. As we have seen, Gibson et al.’s decision to ignore the internal segment- or stroke-constituency of letters seems to have carried with it a heavy penalty; they should not have ascribed their distinctive features to such high-level units. In short, they mistook “morphemes” for “phonemes.”

On the other hand, Eden and Halle’s own distinctive features (aside from the four we added)—“Arch,” “Loop,” “Hook,” and “Bar”—are effectively strokes themselves; they cannot be combined, and so the small set of strokes each defines—internally differentiated by “Raised,” “Mirrored,” etc.—is with respect to these original four features, atomistic. We suggested that “Hook” and “Loop” did not strike us as atomistic primitives; but more generally “Arch” and “Bar” are surely not primitives either, since both can easily be broken down in terms of Gibsonian distinctive features like “Vertical,” “Curved,” and so on. Since we have already suggested that Gibsonian features may be valid, it seems that Eden-Halle have made a mistake at a lower level comparable to Gibson et al.’s at the higher: that is, they mistook “phonemes” for “distinctive features.”

As we see, then, the two illustrative analyses we have been examining have similar but almost complementary shortcomings, and a first step towards improving both analyses might be importing into each the best attributes of the other. Roughly, Eden-Halle attacked the right domain (their phoneme-analogs were strokes, not letters), while Gibson et al. came closer to employing the right kind of distinctive features (theirs were much more freely combinable, and had some psychological warrant). Thus the obvious next move should run something like this: the printed majuscules should be dissected into their proper strokes—as Eden and Halle did for the cursives—and those strokes should then be analyzed in terms of Gibson-like distinctive features (“Vertical,” “Curved,” and so on).<sup>13</sup> And in fact this is a necessary, though scarcely sufficient, step.

The alert reader will have seen that any such step, however, can also be viewed as carrying a penalty, for if letters are to be broken down into their strokes before being characterized (stroke by stroke) in terms of distinctive features, then they can no longer be characterized by “Symmetric,” a feature which necessarily applied to the letter as a whole. We might call “Symmetric” a “global” distinctive feature, one which in our proposed reanalysis would have to apply over more than one segment rather like an Harrisian phonemic long component (Harris 1951); other “global” features in this sense would be “Cyclic,” “Intersection” (which of course must deal with two line-segments), and perhaps “Vertical (and Horizontal) Terminates” (which deal with the absence of two line-segments where two could have been present). However, the loss of these “global” features is only temporary, since they are all features that can be calculated, or derived, from sequences of line-segments expressed without them. (A system can recognize “Symmetry” by inspecting underlying abstract representations, just as we can; several examples of such calculations will be exhibited in Part II.)

13. Lest anyone think that, on the contrary, the proper next step should be to combine Eden-Halle-like features with the Gibson et al. choice of letter as “phoneme,” I have constructed the chart of Figure 6 as a counterargument. As is plain from Figure 6, where several imaginative ploys have been put to use, the case is a dead-end, because without being able to pinpoint where in the letter the distinctive features fall, the description is hamstrung.

## 2. *Conclusion.*

We now return to our starting point: the desiderata that we should ask a serious characterization of “the alphabet” to realize. Our point of departure was the observation that iconic analyses in search of something more than “more rigor” must be judged by criteria of adequacy; this led us to consider what sorts of psychological evidence might be brought to bear on the achievement of “cognitively descriptive” or even “explanatory” adequacy. We used two accomplished and well-known iconic analyses, having a common ancestor, as illustrations. The first, Eden and Halle, was apparently designed with no psychological relevance in mind at all; and, not surprisingly, it fails to have much. The second, Gibson et al., was erected on the basis of several direct psychological importations; but even so it failed to achieve much more than the sort of “observational” adequacy that Eden and Halle achieved, because if the psychological evidence is all drawn from discrimination studies, and if the analysis itself is aimed only at explaining discrimination (among attestable members of the object set), then discrimination—or, in other words, human pattern-recognition—is all that can be achieved, howbeit via features having some psychological warrant or other. We found fault with Gibson et al. regarding their system’s discriminations; but we found graver fault with their system’s apparent *inextensibility* to accommodate additional (and fairly obvious) psychological information.

Building grammars without success criteria is, to paraphrase the national bard, like playing tennis without a net. It is too easy to propose a new characterization of the alphabet, generally of an alphabet in some new and untoward font, in terms of which some theory or other can be upheld. These exercises are in most cases interesting mainly for whatever immediate utility they may have (as, in a computer system). We will return to this topic in Part III of this series of papers, “Further Complexities” (that is, “Further Perplexities”).

But this brings us to a convenient breaking-point.

I should like to acknowledge the counsel of D. Jacobs; J. I. Yellott, Jr.; W. H. Batchelder; A. K. Romney; L. Narens; S. Haviland; M. Braunstein; and George Kaplan. All faults are theirs.

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## The Research Connection

*Visible Language* is broadening its role as a disseminator of often inaccessible information. It is becoming a vehicle for the exchange of information on research and experiment in design schools. Where are visible language innovations, insights, technological developments, teaching experimentation, and perceptual explorations taking place? We intend (with your co-operation) to find out. We are beginning a census of design schools and design departments with reference to their programs for research and experiment in visible language. It is our plan to collect information and develop a taxonomy which will relate similar and complementary design research. *Visible Language* will report on work recently done or in progress as well as selected research monographs—functioning as a clearinghouse for designers involved in similar research projects.

The value of such an undertaking became clear last summer as I participated in the Edugraphic conference sponsored by ICOGRADA at the University of Alberta in Canada. I was specifically involved in the workshops on research and experiment in visual design. Many of the workshop participants desired better access to research and improved contact possibilities with those interested in similar areas of research.

The *Visible Language* census is designed to fill this void. During the coming months, you will receive a census form soliciting information. It is your collective participation that will make this census a significant resource. Any inquiry regarding this project can be directed to: Visible Language, Prof. Sharon H. Poggenpohl, The Institute of Design, 3360 South State Street, Chicago, Illinois 60626 USA.

# The Quipu as a Visible Language

Marcia Ascher and Robert Ascher

The Inca are often cited as a civilization “without writing.” But writing is more than a record of language sounds placed upon familiar materials. The media of the Inca were devices made of cotton cords that are called quipus. This introduction to the quipu is based upon a recent study of most of the world’s known quipus now spread throughout three continents and concentrates on what we infer to be the way the physical elements of quipus are combined to create a symbolic structure; i.e., the representation of numbers, the expression of N-dimensional arrays, and hierarchical configurations. A discussion of the connections between the quipu and civilization includes: (1) cotton as a material which carried its own message for the Inca; (2) reflections of the quipu in non-media domains of Inca civilization; and (3) the purpose of writing in early civilization.

Around five thousand years ago a major change in human history was well underway. Compared to the preceding several million years, a new kind of human organization had emerged more or less simultaneously at several places on earth. The term civilization is applied to the phenomena, and it is used with reference to its local manifestations: we speak, for example, of Chinese civilization or of Egyptian civilization.

It is one thing to discuss civilization in sweeping terms and quite a different matter to describe exactly what it is. One approach is to compose a list of things that characterize early civilizations, such as strong centralized authority, massive building programs, and occupational specializations. Almost all lists show “writing” in a position very close to the top.

The problem is that some human organizations that appeared to be very much like civilizations in all other respects did not “have writing.” What are we to make of a people who built a road system that ran thousands of miles linking cities and villages,

maintained store houses, irrigation canals, and mines, and indeed kept records, all without writing? The Inca, who are at issue here, continue to be one of the few cases that do not fit the list makers' definition.

In the past the solutions to the problem of a civilization "without writing" have been to neatly skirt the issue, or to deny the civilization. Skirting around it, for example, is done by Rowe (1946): "The fact is that the Andean peoples possessed substitutes for writing which were so satisfactory that they probably never felt the need for anything more elaborate." The strength of feeling of those who hold the alternate opinion is evident in the following response to the above: "Such a conclusion [that proposed by Rowe] is in praise of intellectual castration; it belies the whole of culture history. For of all discoveries and inventions, writing gave us the continuity of that we are pleased to call civilization . . ." (Von Hagen, 1961). The main "substitute" for writing that Rowe refers to is a device called a quipu. This, for the moment, can be described as a device made out of cotton cords.

Most opinion favors the first solution illustrated by the citation from Rowe: that is, (a) writing is implicitly retained as a mark of civilization; (b) the Inca were a civilization even if they did not "have writing" because (c) they had something else, namely quipus. It is interesting that this solution is reached from very different starting positions. In the context of orthodox Marxist analysis, for example, Valcárel (1965) asks why it is that the Inca did not write when Marxist-Leninism has demonstrated that all civilizations follow the same road. His answer is that the Incas had, in particular, quipus, and that these devices when fully deciphered will resolve the issue.

It seems that the favored solution results in a paradox. Our approach began with the suspicion—a suspicion that quickly grew into a working hypotheses—that the ordinary conception of writing is too restrictive. If the Inca "substitute" is a visible language, the paradox vanishes. At the least, quipus (and other similar devices) should force us to reconsider what is meant by writing.

Some authors—most recently Pirsig (1975)—go so far as to claim that the sacredness attached to the spoken and written word

is culture-bound to western civilization. In our view, writing is clearly not a record of speech only. A glance at a musical score, a chemical journal, or a mathematics text, is sufficient to demonstrate the point. Quipus were seen by westerners in the sixteenth century. These people wrote chronicles, but they did not understand what they beheld. They thought that quipus were writing—that is, written speech. When it was finally determined that quipus did not record the sounds of language (Locke, 1932), any value attached to them disappeared. It is as if language written down, say in alphabetic letters, is so closely associated with writing that other forms of visible language do not count: this is the western bias that turns everything else into a “substitute.”

What follows is a discussion of the quipu organized around two issues. In the first, focus is on selected aspects of the way physical elements are combined to create a symbolic structure. This is followed by a discussion of the connections between the quipu and civilization. Many issues of a more than elementary nature are left out; further, the issues that are discussed are not treated exhaustively. In the end, the reader should be in a better position to appreciate the quipu as a visual language medium.

### *Preliminaries*

*Basic quipu description.* A quipu has a main cord from which knotted cords are suspended. When laid flat on a table, with the main cord placed horizontally, the majority of suspended cords fall one way (downward) but sometimes a few are directed upward. Closer examination shows that not all cords are attached to the main cord; some are attached to these attachments. The attachment is tight so that all cords have a fixed position on whatever cord they are hung. The cords are made of colored cotton. Some rare exceptions are made of colored wool. The knots on each cord are formed into clusters; that is, a few knots, then a distant space with no knots, then a few more knots, etc. The knots are of three different types.

Figure 1 is a schematic of a minimal quipu. (1) The *main cord* has a color, say brown (B). The ends of this cord are free and can be distinguished from each other by the manner in which they are finished. Hence, uniformly, directionality can be attributed to the

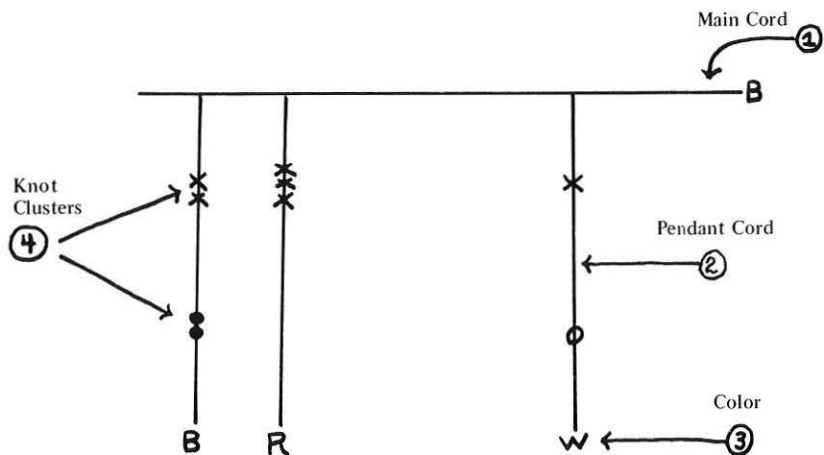
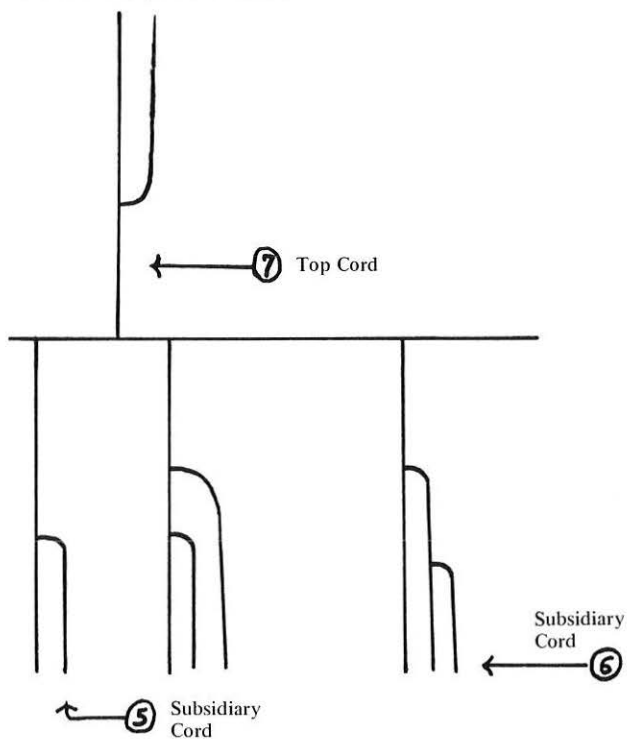


Figure 1. Schematic of a minimal quipu showing (1) main cord, (2) pendant cords, (3) color designation, and (4) knot clusters.

Figure 2. Schematic of a quipu with subsidiary cords and top cord in addition to main cord and pendant cords.



main cord. (2) *Pendant cords* are suspended from the main cord. They have a distinct position on the main cord. Notice that a larger space separates the second and third than separates the first and second. (3) A *color* is associated with each pendant cord, say brown (B), red (R), white (W). (4) *Knot clusters* appear on the pendant cords. Here x, ●, o denote the three different knot types. The clusters are defined by the spaces between them as well as the knots in them. Some pendants have no knots.

In Figure 2 additional cords have been included. (All, of course, have colors and most have knots as described above.) (5) *Subsidiary cords* are attached to the pendant cords. A pendant cord can have more than one subsidiary as on the second cord; or, as on the third cord (6), *subsidiary cords* are attached to other subsidiaries. (7) *Top cords* are directed upward (as compared to pendants which are considered downward). Top cords too can have subsidiaries.

Quipus vary considerably in size and elaboration. The quipu in Figure 1 is minimal in that it contains the most basic elements and few cords. Small quipus have about 8 or 10 pendants, most have between 40 and 150 pendants, and large ones can contain over 1,000 pendants. The cords vary in length from about 15 cm. to 75 cm., but on any individual quipu most of the pendants are about the same length. Many quipus, but not all, have subsidiaries. An individual quipu can have as few as 1 subsidiary or, as in Figure 2, more subsidiaries than pendant cords. Some quipus have a few top cords on them. These are the most common elements; other elements appear on individual quipus, or on a few quipus. Figure 3 is a photograph of a quipu showing cords and knots.

*Recent History.* In the belief that quipus were ungodly, the western conquerors of the Incas undertook to destroy quipus by burning. From the point of view of the Incas, it was godly to bury with the dead the trappings they used in life. Hundreds of years after the Inca state had passed, westerners started to dig up the graves. This time the quipus were given, sold, or otherwise found their way to private collections or to major museums in North America, South America, and Europe. In every case, quipus that are known to us come from graves.

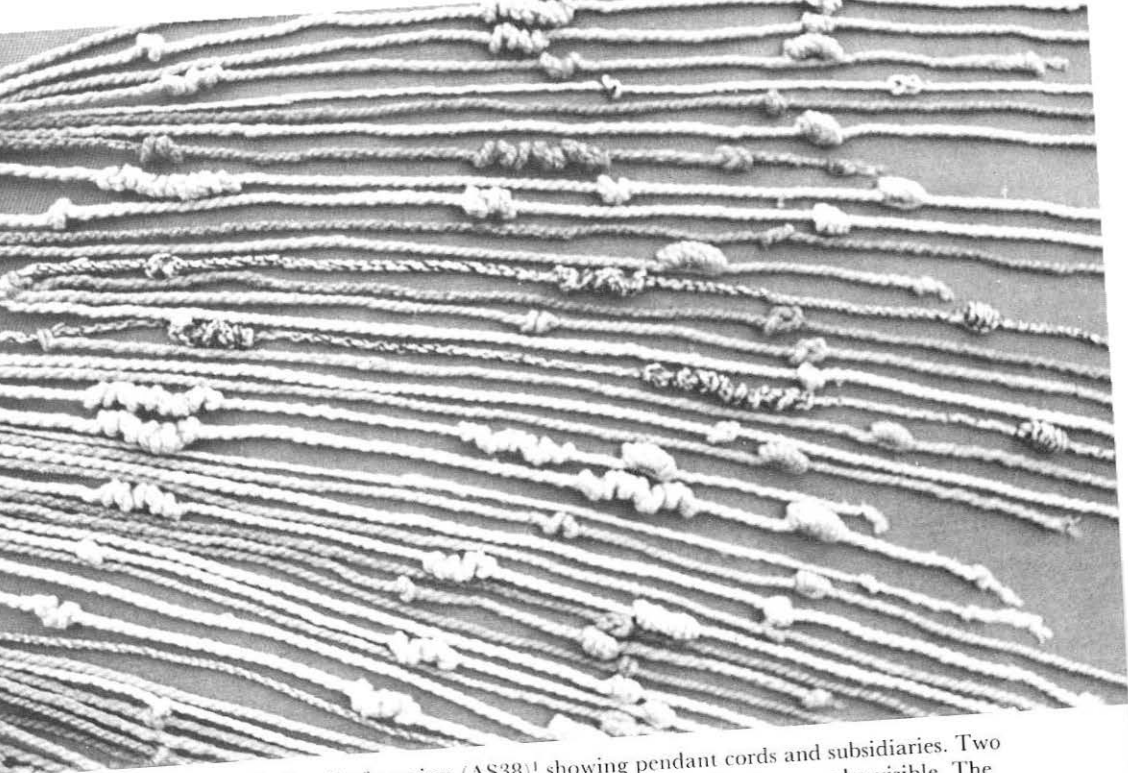
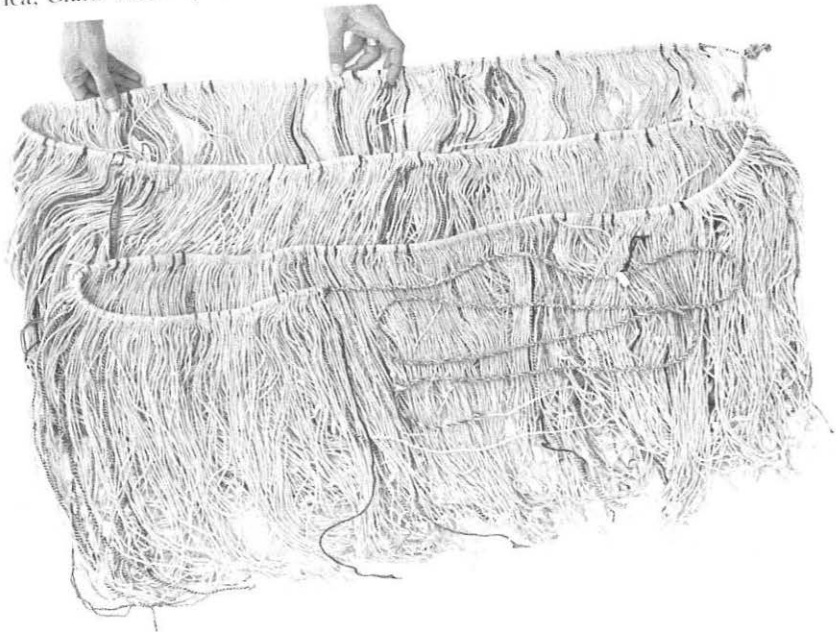


Figure 3. Detail of a quipu (AS38)<sup>1</sup> showing pendant cords and subsidiaries. Two of the three major knot types—single knots and long knots—are also visible. The quipu is in the collection of the Museo Nacional de Antropología y Arqueología, Lima, Peru. Photo by the authors.

Figure 4. The largest known quipu (AS69). Collection of Percy Dauelsberg, Arica, Chile. Photo by the authors with the permission of Mr. Dauelsberg.



Cotton quipus survived in graves where conditions of preservation were favorable; that is, in the desert area between the Andes to the west and the Pacific to the east. The specimens vary widely in condition: some fall apart upon touch; others are as fresh as yesterday's purchase of cord. With some exceptions, quipus were deliberately separated from other items in the graves; when the grave site is given, it is usually identified in vague terms such as by the name of a nearby city.

Prior to starting our research, about 60 quipus had been published in 14 separate articles and monographs (Ascher and Ascher, 1969). In 1972 we added nine descriptions of quipus to the literature (Ascher and Ascher, 1972). Then in 1974 we began to search for all the remaining quipus in the world. So far, we have located about 475 specimens that are in 30 different places spread across three continents.<sup>2</sup> As of now, we have studied 400 specimens and about half of these are individually recorded in schematics, drawings, photographs, tables, and words (Ascher and Ascher, 1975).<sup>3</sup> Any interested person, we believe, will be able to use our primary descriptions to test independently or formulate his own notions.

Included in the new data are the largest specimens in the world. For example, the specimen shown in Figure 4 contains 1800 pendant cords. Also in this group are quipus that are hung from carved wood frames (Figs. 5 and 6). Our research turned up several instances where the context of the quipu recovery can be reconstructed. Instead of the generality that quipus are found in graves, we now have retraced the association of some particular quipus with fragments of pottery, pieces of cloth, baskets, decorated bags, and other objects. Perhaps of greater importance, we know of cases where a group of quipu can be assigned to a specific quipu maker. The generalizations that follow are based upon all of this work.

### *The Symbolic Structure*

In the preliminaries, a quipu was described as consisting of cords that have knots, colors, and particular positions in a spatial configuration. On most of the quipus the knot clusters form a symbolic representation of numbers. Once each cord is read as a number, a

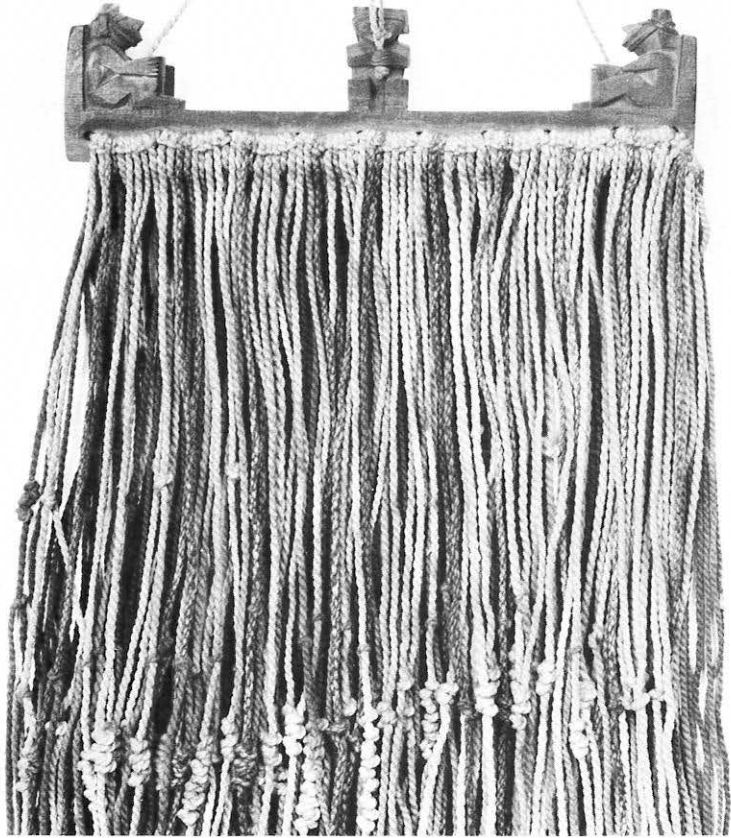


Figure 5. An unusual quipu (AS136) in that it is suspended from a carved wood bar. The lower part of the pendant cords are not shown in the photograph. Collection of Museum für Völkerkunde, Berlin, Staatliche Museen Preussischer Kulturbesitz, Dept. Amerikanische Archäologie. Photo by the Museum at the request of the authors.

Figure 6. A close-up of one of the three carved figures on quipu AS136.



quipu can be viewed as a spatial array of differently colored numbers. Since it is a carefully constructed array, the configuration which is defined by the color and placement of the cords also constitutes part of the overall symbolic system of the quipu. Two types of configurations are included here for close scrutiny. They have been selected because of their frequent appearance and because their logical underpinning cannot be ignored when such specimens are studied further. Both are amenable to being expressed in familiar terms keeping in mind that it is only the logic that is analogous. In both cases we focus first, through example, on the logic with which we are concerned and then on the expression of this logic using the quipu elements that have been introduced. The discussion of two such different configurations, and the fact that these can be combined to form one more complex configuration, should convey that the quipu is not a single-purpose device.

Since the configurations to be discussed both depend on cords being read as numbers, we first look at the way numbers are represented symbolically and some ideas involved in such a representation.

*A positional number system.* If, in answer to the question “How many?”, 5 fingers are held up, or 5 pebbles are amassed, or 5 scratch marks are made, the respondent is merely carrying out a matching process by placing 2 sets of objects in 1-1 correspondence. More abstraction is shown by developing a name or symbol to represent the quantity 5. Also, the use of a special name or symbol for each quantity indicates that the concept of order among quantities exists. Because they are on strings, the number representation on quipus have frequently been erroneously classed with the less sophisticated one-to-one string records. The knots used on the quipu are, instead, a symbolic representation. The representation they use is, in fact, basically the same as ours: it is a base 10 positional system.

A base X positional system means that the value of each position is dependent on a different power of the base X. In our number system, each consecutive position, moving toward the left, is one higher power of ten. For example:

$$9432 = (9 \times 1000) + (4 \times 100) + (3 \times 10) + (2 \times 1)$$

In our system, only 10 different symbols (0, 1, 2, . . . , 9) are needed. The placement of the symbols and the knowledge that the base is 10 is all that is needed for the representation of any value. To use, for example, a base 6 positional system, 6 different symbols are needed and each consecutive position is a higher power of 6. Using the symbols (0, 1, 2, . . . , 5), the base six numbers 231, 154, and 11 correspond to what in base 10 are symbolized as 91, 70, and 7.

$$\begin{aligned} 2 \times 36 + 3 \times 6 + 1 \times 1 &= 9 \times 10 + 1 \times 1 \\ 1 \times 6^2 + 5 \times 6 + 4 \times 1 &= 7 \times 10 + 0 \times 1 \\ 1 \times 6 + 1 \times 1 &= 7 \times 1 \end{aligned}$$

In the history of number representation, non-positional systems and positional systems with other bases have been used. European adoption of the Hindu-Arabic base 10 positional system happened sometime in the fourteenth century. Prior to that, the non-positional Roman numbers were in use.

In order to appreciate the significance of the invention of a positional system, briefly consider the non-positional Roman system. There are distinct symbols for 1, 5, 10, 50, 100, 500, 1000 (I, V, X, L, C, D, M); these are added or subtracted to arrive at other values. When the symbols are placed in descending value moving toward the right, they are additive (VII = 5 + 1 + 1). When a smaller valued symbol precedes a larger one, it is subtractive (IX = 10 - 1). The subtractive property is usually only used with single symbols (i.e., 90 = XC while 80 = LXXX rather than XXC) that are close valued (i.e., 95 = XCV rather than VC) but not necessarily (i.e., 1900 = MCM rather than MDMCD). It can be observed that the order of magnitude of numbers is not related to the size of their representation. For example, M is greater in value than XXXVIII. In the positional system, the size and value are related: 3724 is greater than 899. Another important contrast is that in the positional system, no new symbols need be introduced as the order of magnitude grows. For example, try to write the equivalent of 4,200,000,000 in Roman numbers. Apparently, although we rarely see them now, horizontal strokes above a number were used to indicate thousand-fold and vertical strokes on the sides to indicate hundred thousands.

$$\begin{array}{l} \text{CDXX} = 420 \\ \text{XLII} = 42000 \end{array}$$

$$\begin{array}{l} |\text{XLII}| = 42000000 \\ |\text{MMMMCC}| = 4200000000 \end{array}$$

Most importantly, the use of the positional representation simplifies arithmetic as the symbols are manipulated in a formal repetitive way to arrive at results. In a positional system, in order to add 2 values, the rightmost positions are lined up, and starting at the right, addition is done position by position. If the sum of the 2 digits in a position is less than 10 (or whatever base is used), the value is recorded and one moves on to the next position. If the sum is greater than 10, the excess above 10 is recorded, and a 1 is added into the next position. Thus, to add any 2 values, the only knowledge needed is the sum of any 2 digits. This is clearly not the case with a non-positional system where the relative values of the symbols and their specific placement must be considered:

$$\begin{array}{r} \text{CCXLVII} \\ + \text{CCCXII} \\ \hline \text{DLIX} \end{array} \qquad \begin{array}{r} \text{DCCXXVII} \\ + \text{DXLVI} \\ \hline \text{MCCCLXXIII} \end{array}$$

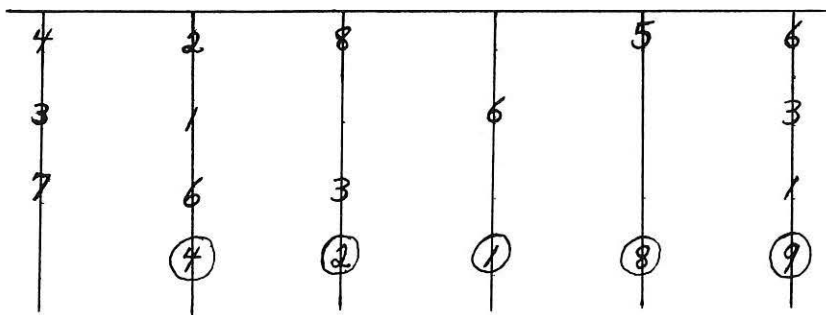
Although the greater flexibility and simplicity of a positional system makes it preferable, the choice of base is completely arbitrary. For example, most modern computers work in a base 2 (binary) system because of the ease of electronic representation and manipulation when only 2 different symbols are involved. Many people working directly with computers become adept at the use of a base 8 (octal) system not only because of its ease of conversion to base 2 but also because of its more concise representation of values [Ex. 110011 (base 2) = 63 (base 8) = 51 (base 10)].

The quipu maker used a base 10 positional system. From the above discussion, it should be clear that although this is most familiar to us, the Inca use of this representation was neither necessary or to have been expected. On each string there are clusters of knots. Each cluster contains 1 to 9 individual knots. Each consecutive cluster position, moving from the free end of a cord to where it is attached to another cord, is one higher power of 10.

A crucial concept in the development of a positional system is the concept of “zero.” The concept of zero is a big idea in mathematics and still causes problems for schoolchildren. The number 407 is quite different in value from the number 47: a symbol for

“none” or “nothing” is placed in the second position in order to have the 4 fall in the third position. The concept of zero can be divided into two parts: first—the understanding that positions containing nothing contribute to the value of a number; second—that a special symbol is necessary for the representation of “nothing.” In the absence of a special symbol, there must be means of distinguishing positions; nevertheless some ambiguity can remain.

The quipu uses the idea of zero with no special symbol for zero. Instead, two tactics are used to make the representation clear. One is the type of knots used in the units cluster differs from the type of knot used in the rest of the clusters. The knot type is standardized: long knots and figure eight knots for units, single knots for the others. Secondly, the cluster positions are aligned from string to string, and so a space left on one string becomes apparent when related to the others. No problem is found when reading the following set of numbers (transcribed with our symbols for 1-9; circled for units; no zero symbol; and increasing powers of 10 from bottom to top):



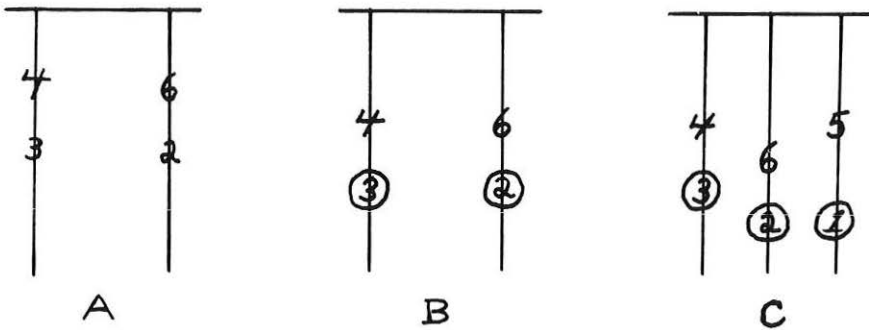
While for the most part the lack of a symbol for zero causes little ambiguity in the reading of quipus, two types of problems do arise. One is inherent in the symbolic representation, and the other is due to the fact that, as with any handwritten document, we are dependent on the “penmanship” of the quipu maker. The first problem is this: if *all* the numbers on a quipu lack knot clusters in the same position, there is no way of knowing that the position exists. For example, if an entire quipu consisted of cords carrying

430 and 620, it would look like Figure 7A. This is indistinguishable from 4300 and 6200. The missed position could also be between clusters. For example, Figure 7B could represent 43 and 62 or 403 and 602 if these were the only values present. The second problem is that ambiguity arises when knot clusters have not been carefully aligned. For example, the numbers in Figure 7C might be 43, 62, 51; or 403, 62, 501; or even 43, 62, 501.

If there were no means of corroborating this numerical interpretation, it would remain only a hypothesis. The evidence that convinces us comes from the juxtaposition of the strings. When we read each cord as a base 10 number and further examine the colored spatial array of these numbers, we find some numerical relationships that cannot be due to chance. The simplest of these is that on several quipus, a single cord dangles from the end of the main cord and when all the pendants are interpreted as base 10 numbers, and the single end cord is similarly interpreted, it is found that the end cord number is the sum of all the other numbers.

*N-dimensional arrays.* From the color and spatial arrangements of the cords, logical relationships between numbers can be inferred. Before dealing with quipus, let us focus on the ideas of matrices, subscripts, and dimensionality. Suppose we have our standard media, namely pencil and paper, and are given the following information: the costs of 4 different automobiles sold in Detroit in

Figure 7. Quipus with ambiguous numbers. (Digits represent knots in a cluster, circle indicates units position).



	1973	1974	1975
car 1	2841	2963	2900
car 2	3442	4013	4207
car 3	3380	3365	3162
car 4	2964	3268	3574

Figure 8. A two-dimensional array.

Figure 9. A three-dimensional array.

	DETROIT			NEW YORK			LOS ANGELES		
	1973	1974	1975	1973	1974	1975	1973	1974	1975
car 1	2841	2963	2900	2763	3605	3120	2941	2990	3002
car 2	3442	4013	4207	3084	3712	4113	3540	4089	4300
car 3	3380	3365	3162	2961	3364	3248	3470	3378	3251
car 4	2964	3268	3574	2964	3486	3447	3012	3300	3600

1975 are 2900, 4207, 3162, and 3574 dollars. These costs can be recorded as a one dimensional array: (car 1, car 2, car 3, car 4) = (2900, 4207, 3162, 3574). If we were given the cost of each of the cars for several years, a two dimensional array (Fig. 8) could be used to record them and retain both the distinction as to the car and the year. This two dimensional array can be described as a matrix containing elements  $a_{ij}$ , where  $i=1, 2, 3, 4$  and corresponds to rows (cars) and  $j=1, 2, 3$  and corresponds to columns (years). Hence,  $a_{13}=2900$ ;  $a_{42}=3268$ ; etc.

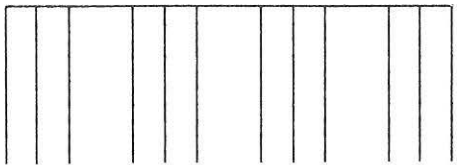
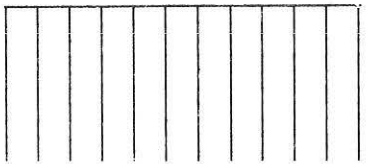
Let us add another descriptor: suppose we are given the cost of each of the 4 cars, for each of the 3 years, for each of 3 cities. To record the costs and retain the 3 distinctions, another spatial dimension, in addition to rows and columns, is needed. Instead, to remain on this 2D page, it might be more readable to resort to 3 tables side by side (Fig. 9).

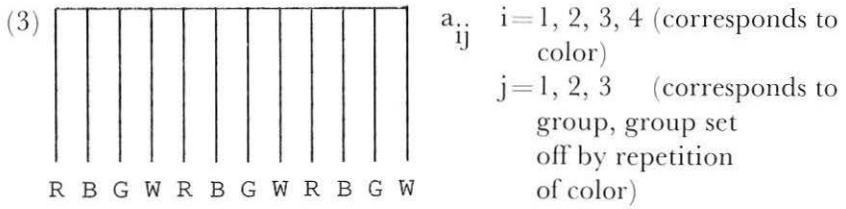
The elements in our 3D array can be described as  $a_{ijk}$   
 $i=1, 2, 3, 4$  corresponds to row (car)  
 $j=1, 2, 3$  corresponds to column (year)  
 $k=1, 2, 3$  corresponds to table (city)

Whether actual spatial dimensions are associated with each descriptor (as in the 1D and 2D examples), or whether arbitrary and ingeniously arranged tables are used when more descriptors are involved, the format of the array is intended to convey the relationship between the values. The subscript notation conveys only the structure and not the values themselves. The 3D example conveys that there are 3 descriptors (hence 3 subscripts  $i, j, k$ ), 2 of them with 3 states each (hence  $j$  can equal 1, 2, or 3;  $k$  can equal 1, 2, or 3) and the other with 4 states (hence  $i=1, 2, 3, 4$ ). The correspondence of subscript  $i$  to row,  $j$  to column, and  $k$  to table, gives each value in the original array an identity in terms of the different states of the descriptors (ex.  $4207 = a_{231}$ ). It is important to understand that the subscript notation describes the *classificatory relationship* of the values to each other rather than any algebraic or numerical relationship.

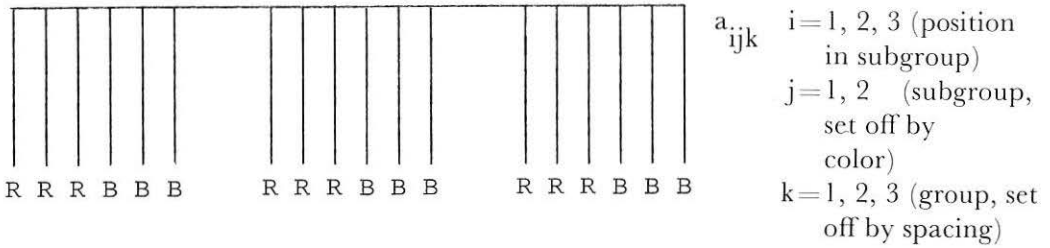
When we find that this subscript notation provides a convenient form of description for a quipu, we infer that we are dealing with a collection of numbers similar to the above—that is, values recorded in several dimensions. Since the quipu consists of a horizontal main cord where each pendant along the cord represents a number, it is basically one dimensional. However, through the use of color and spacing, 2, 3, and 4 dimensional arrays in fact occur on actual quipus.

Consider the following arrangements (where R denotes Red, B denotes Blue, W denotes White, G denotes Green); all are two dimensional arrays of the kind commonly found on quipus.

- (1)   $a_{ij}$   $i=1, 2, 3, 4$  (corresponds to groups set off by spacing)  
 $j=1, 2, 3$  (corresponds to position in group)
- (2)   $a_{ij}$   $i=1, 2, 3, 4$  (corresponds to position in group)  
 $j=1, 2, 3$  (corresponds to group, group set off by repetition of color)



Similarly, three dimensional arrays are formed such as:



In order to have a great variety of colors available, the quipu maker created new colors by combinations of his basic colors. Using 3 standard weaving techniques to combine colors, 2 basic colors could be used to designate 6 different states and with 3 colors as many as 23 different states could be designated. Another separation technique, in addition to color and spacing, is the use of special markers. The markers can be pendant strings with no numbers on them that stand out because they are much longer, much shorter, or differently colored. Alternately, some conspicuous flag is found: for example, several short strings are wrapped around the main cord and tied together so that they form a cotton bump.

On actual quipus, separation and identification techniques are combined to yield many different arrays. Some arrays are:

AS99	$a_{ij}$	$i=1, 2, \dots, 16$ $j=1, 2, 3$	AS114	$a_{ijk}$	$i=1, \dots, 16$ $j=1, \dots, 10$ $k=1, 2$
AS115	$a_{ij}$	$i=1, \dots, 7$ $j=1, \dots, 8$	AS121	$a_{ijkm}$	$i=1, \dots, 10$ $j=1, \dots, 7$ $k=1, 2, 3$ $m=1, 2$

The notation permits a compact statement. But in the brevity, one should not lose the sense of complexity, for to do so would be to miss the power of the quipu as an expressive symbolic device. Consider, for example, AS114 above. This is a three-dimensional array containing 320 pendants; 160 of the pendants are formed into 16 groups of 10 pendants each. All the pendants in a group are united by sharing the same color; and each group is distinguished from the one next to it by being a different color. Then, separated by a large space on the main cord, there are another 160 pendants. These also are formed into 16 groups of 10 pendants each by color. The color pattern on the second part of the quipu is the same as on the first part. Hence,  $k=1, 2$  corresponds to part set off by space and repetition of color pattern;  $i=1, \dots, 16$  corresponds to group set off by color; and  $j=1, \dots, 10$  corresponds to position in group.

After it has been observed that a given quipu is an N-dimensional array, numerical or algebraic relationships between values can be sought. When relationships exist between the values and are consistent for some entire category, we feel confident that it is more than a spurious observation because it depends on both the form and the content of the array. Look once more at the 2D example (Fig. 8). An examination of the values shows that:

$$a_{13} > a_{32} > a_{13}$$

Since this has no consistency according to category, it is valid but not of any particular interest. However, the statement that

$$a_{2j} > a_{ij} \text{ for all } i \neq 2, \text{ all } j$$

says that each year car 2 cost more than each of the other cars. Looking next at our 3D example (Fig. 9), we see that, in fact,

$$a_{2jk} > a_{ijk} \text{ for all } i \neq 2, \text{ all } j, \text{ all } k$$

that is, each year in each city car 2 cost more than each of the other cars. This must be considered more than chance.

Figure 10 is the same 2D example but it has been augmented by (1) an additional bottom row, and (2) an extra value placed at the lower right. Before jumping to the conclusion that the number of states of a descriptor has been increased, look at the values that were appended. The elements in the new row (row 5) consist of the sums of their respective columns. The extra value is the grand

	1973	1974	1975	
car 1	2841	2963	2900	
car 2	3442	4013	4207	
car 3	3380	3365	3162	
car 4	2964	3268	3574	40079
	12627	13609	13843	

Figure 10. The two-dimensional array shown in Figure 8 augmented by an additional row and an extra value.

total. Similarly, another column would have been added if row subtotals were to be included. Values which are the sum of other values are now included, but *the array has in no way turned into a calculating device and there is no way of knowing how or where the calculation took place*. It cannot even be stated with certainty whether summing of the 4 values in a column led to the 5th value, or whether the 5th value was subdivided into the 4 values above it. Nevertheless, we can conclude that the concept of addition is involved. Also, the grand total could be viewed as the sum of all 12 values in the original 2D array or as the sum of the 5th row in the augmented array. In either case, the subtotals are not simply a step on the way to the grand total since they have been retained as independent pieces of information.

Just as in our paper and pencil example, one set of subtotals could have been associated with rows and another set with columns, so the different subtotals on N-dimensional quipu arrays adhere to their dimensional indicators. Thus we find that on a quipu such as arrangement (1) above, the subtotal of each of the 4 groups is associated with the group by the inclusion of an additional pendant in each group. When a sum cord is included with a group, it is spatially distinguished by being tied to the main cord so that it falls upward rather than downward! On a quipu such as (3), if the subtotals associated with each of the colors were included, they would constitute an additional group containing each of those colors. Finally, a grand total when present is anomalous, as it was in our paper and pencil example, and would usually be spatially distinguished by simply dangling from the end of the main cord.

To conclude our discussion of the N-dimensional arrays, we note

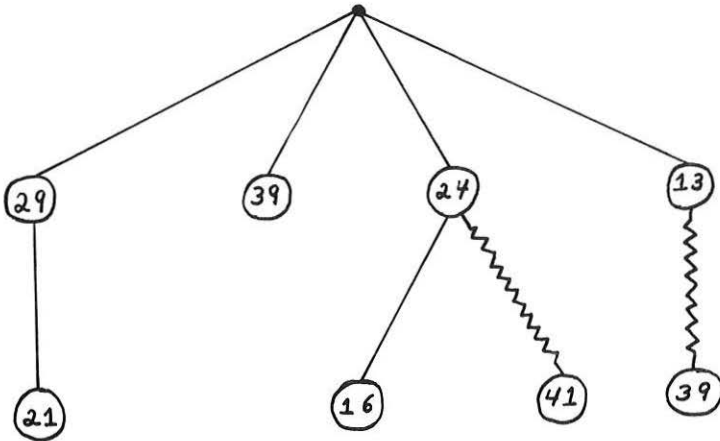


Figure 11. A tree diagram with two levels.

many one dimensional arrays have grand totals, several two dimensional arrays contain upward directed subtotals or an end group of subtotals, and some three dimensional arrays contain both groups that are subtotals of other groups as well as an end group of subtotals that include them. Regularities consistent throughout categories vary in type with one of the most unusual being a fixed proportionality.

*Trees and hierarchies.* We turn now to a discussion of a second, completely different type of array. Before looking at their expression as a quipu configuration, attention is given to the ideas of tree diagrams and hierarchies.

Suppose we start once again with our standard media of pencil and paper and are given the following information: 8 people (Mr. A and his son; Mr. B; Mr. C and his son and daughter, and Mr. D and his daughter) went fishing on one boat and caught 29, 21, 39, 28, 16, 41, 13, and 39 fish respectively. We want to record the number of fish caught by each family on the boat but retain the identification by generation and sex. Using the natural hierarchy of generation, we record the catch of each father and below that (connected by a straight line for a son and a wiggly line for a daughter) the catch of his children (Fig. 11).

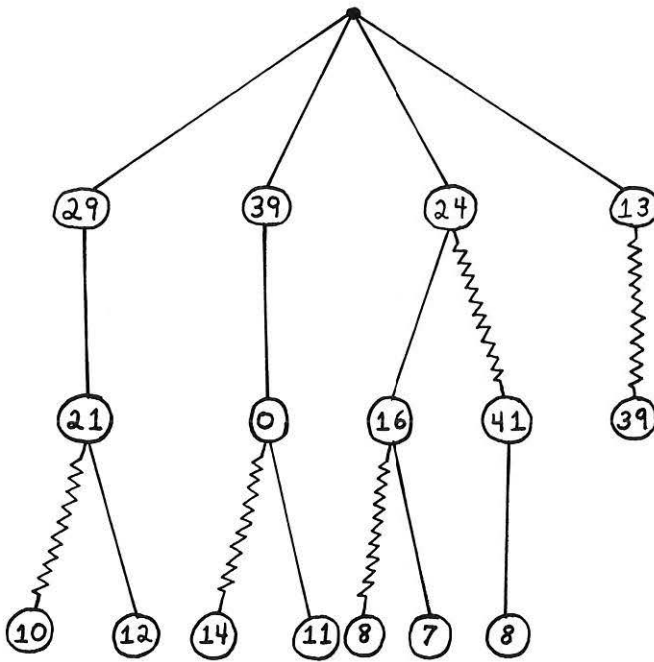


Figure 12. A tree diagram with three levels.

This diagram has 2 levels; the first corresponds to the fathers and the second to the children. As one moves from each value in the first level to the second level, it is possible to branch into 2 values. Although Mr. B is alone so his family is only represented by 1 level and Messrs. A and D each have only 1 child with them, the diagram as a whole has 2 levels and 2 possible branches to the second level.

Let us increase the number of people that were on the boat: Mr. A's son brought his son and daughter, Mr. B brought his son's son and daughter, Mr. C's son brought his son and daughter, and Mr. C's daughter brought her son, who caught 10, 12, 14, 11, 8, 7, 8 fish respectively. To include this information, another level is added to the diagram. All the information has been recorded on a tree diagram (Fig. 12).

This diagram has 3 levels with 2 possible branches from each value on the first level to the second level and 2 possible branches from each value on the second level to the 3rd level. (Notice that although Mr. B's son was not present, he has been included with a

catch of 0 in order to place his children in the appropriate generation.)

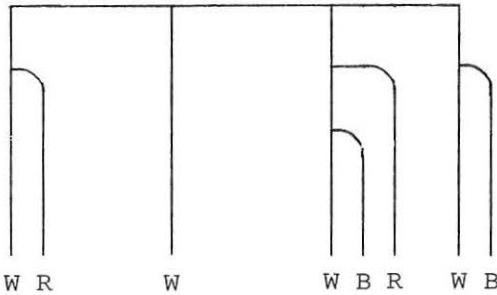
With a tree diagram, it is easier to look for regularities consistent across levels or consistent with respect to branches. One can observe, for example, that each of the values on level 1 is greater than the sum of its connected values on level 3; namely, each father caught more fish than all his grandchildren combined.

This problem, as it is stated, can easily be extended to have more fathers on the boat (more starting points), or additional generations (more levels). If it is extended by including more than 1 son and daughter per person, there would be more branches per level, but we would have to decide whether to use the same style connector for each son (or daughter) or to use different style connectors depending on some other characteristic (say, age). Also, the problem has the same transitions from each level to the next, which can easily be modified by, for example, letting the children but not the adults bring friends.

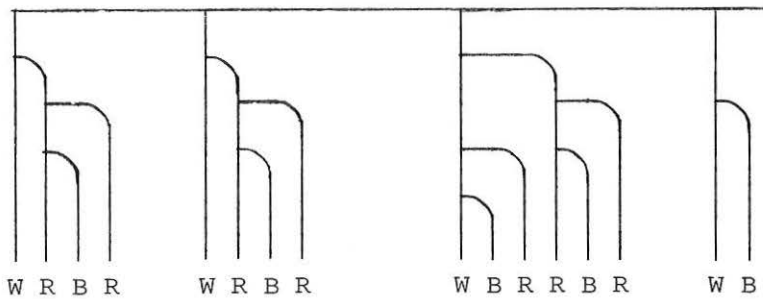
The important feature of any tree diagram is that each item at the bottom can be traced upward in one and only one way passing through each level exactly once as you proceed upward. In drawing a tree diagram, it is crucial that the possible ways to proceed from one level down to the next lower level are clearly defined. Hence, they are most adaptable to describing hierarchical organizational structures whose organizing principle is who reports to whom, or for describing processes with distinct stages which are structured in time.

What we call tree diagrams seem to find a direct expression in the format of quipus; it is as if both contemporary western symboling and Inca symboling approach each other at this point. On many pendant cords there are suspended 1 or more other cords from which there are suspended yet other cords, and so on. With paper and pencil, different symbols to distinguish the branches are needed. In the fish problem, only 2 connectors were used; one represented by a straight line and the other by a wiggly line. The quipu is much less restrictive as different colors are used to distinguish branches. By viewing this array as a tree diagram, we emphasize that cords must be considered as part of a hierarchy where each pendant or subsidiary carries on identification by its

level and branch within that hierarchy. For example, a quipu similar to the 2 level tree diagram (Fig. 11) could look like:



and one comparable to the 3 level tree diagram (Fig. 12):



If, in our example, there were a second boat with 4 families, this hypothetical quipu representation might have adjoined to the first group of pendants another group of 4 pendant cords with similarly Red and Blue colored subsidiaries attached to the pendants and to each other. It could then be described as a two dimensional array

$$a_{ij} \quad \begin{array}{l} i=1, 2 \text{ (group)} \\ j=1, 2, 3, 4 \text{ (position in group)} \end{array}$$

where each pendant is a starting point in a 3 level hierarchy with 2 branches possible from each value from level to level.

An upward directed cord associated with each group could carry the group subtotal. In our example, such a total could be for the entire boat and could be on one pendant alone. Alternatively, the total could be on a pendant with 2 levels of subsidiaries, thus expressing the boat total but keeping the generational distinction;

or, it could be on a pendant with 2 levels of subsidiaries with 2 branches on each, thus keeping both the generational and sex distinctions. On actual quipu there are some group subtotal cords that retain the branches or levels, some that lump them, and some that sum only the pendants and ignore the subsidiaries.

To conclude our discussion of hierarchical arrays, we cite a specific quipu example. The example is chosen to impress the reader with the logical complexity that can be expressed on a quipu—for obvious reasons it cannot be transcribed here. On one quipu the pendants carry up to 5 levels of subsidiaries with as many as 10 branches from each value on some levels.

### *Media and Civilization*

In *Tristes Tropiques*, Lévi-Strauss (1955) tells what happened when the leader of a Brazilian tribal people learned about writing. He takes the story as a point of departure for a discussion of writing in early civilization. The discussion begins, as expected, with the repetition of the self-comforting thought that writing is the most important criterion for civilization, the one that is most worth retaining on the lists of what characterizes civilization. Suddenly, all of the pleasant connotations associated with this thought are thrown into doubt; the author recalls that no sooner did the tribal leader find out about writing than he seized upon it as a means to enhance his prestige and authority. Lévi-Strauss thereupon draws the following inference: “the use of writing for disinterested ends, and with a view to satisfaction of the mind in the fields of the sciences or the arts is a secondary result of its invention—and may even be no more than a way of reinforcing, justifying, or dissimulating its primary function.” And what is the primary function? According to Lévi-Strauss, “the primary function of writing as a means of communication, is to facilitate the enslavement of human beings.” He points out that writing makes its appearance along with oppressive political systems. And that is why, says Lévi-Strauss, writing goes together, for example, with massive architecture: to accomplish the architectural feats of the ancient world, thousands of people had to be assembled and they were taxed to the limits of their strength. Incidentally, Lévi-Strauss insists that the case of the Inca confirm his hypotheses: they were unstable,

they “decomposed” quickly; however politically oppressive the Inca were, the absence of writing supposedly prohibited them from maintaining their position of power.

The last comment can be dismissed as an unsuccessful attempt by yet another author to deal with the “but they have no writing” problem. As for the rest, the evidence can be interpreted as leaning toward support for the notion advanced by Lévi-Strauss. The content of the bulk of early media is statistical and economic; presumably, those in authority needed these data to exercise control. What was wanted was a device to keep track of essential information. In the Andes, Baudin (1961) contends, “The statistical reports of pre-Columbian Peru enabled the Inca and the higher officials to know what the economic condition of the empire was and to act accordingly.” The device they used was the quipu; elsewhere other devices were used.

Theoretical support for the Lévi-Strauss opinion comes from what Max Weber (1952), discussing bureaucracies in general, calls the concept of “official secrets.” “Bureaucratic administration,” says Weber, “means fundamentally the exercise of control on the basis of knowledge.” Those in authority, again citing Weber, “acquire through the conduct of office a special knowledge of facts and have available a store of documentary material peculiar to themselves.”; all of this “is a product of the striving for power.” Now in early civilizations, including the Inca, everything surmisable about scribes and quipu-makers, and everything that is known about the information they recorded, suggests that a privileged appendage of the elite were recording “official secrets” peculiar to themselves and to those whom they served. Writing for what Lévi-Strauss calls “disinterested ends” was indeed thousands of years in the future; in that future, something more than quipus might be required.

A way to characterize a civilization, other than holding up a checklist, is to define its particular style. The search for the style of a civilization requires the identification of basic symbols. The seeker, we think, is left with a sense of having missed the point that comes in the wake of a part by part analytic approach. But the Gestalt, the unity, the underlying principle, is often elusive. We are indebted to A. L. Kroeber (1963) for reminding us of the origins

of the word style: "The etymology is from *stylus*, the pointed rod used for writing on wax by Greeks and Romans. The sense here is metaphorical, as we speak of an inspiring or poisoned pen, of a fluent or a bold hand. A man's style originally was his characteristic, idiosyncratic manner of writing: possibly at first with emphasis on the shapes of his letters, his handwriting, certainly later with reference rather to his choice and combination of words." The icon of Inca Civilization is the quipu; we return here to the original association of the word style with media.

As already stated, quipus are made out of cotton shaped into cords. Cotton cords are light and not especially durable; in this regard, they are more like the papyrus of Egypt than, say, the clay of Babylonia. One theory has it that heavy durable media go with early empires that stress time, and lighter, less permanent materials go with empires that stress space (Innes, 1950). However, this may be, the view from inside Inca Civilization (as contrasted with the "outside" comparative view) points to cotton as the obvious material.

Cotton had been brought under cultivation for the first time in human history along the Pacific coast within sight of the Andes thousands of years prior to the appearance of the Inca. The long period of cotton cultivation and use had important consequences that are directly relevant to the present study. Gayton (1961) puts it succinctly: "The head start, so to say, which textiles had in ceramics, metal, and mural decoration may have established a lasting priority for the textile art as the primary means of visual communication." But there is even more to it than that: over the millenia, and before the emergence of the Inca, cloth took on a peculiar significance for Andean peoples. Commenting on this, Murra (1962) writes: "There is nothing strange in the political use of prestige objects; the novelty consists in the discovery that, in the Andean area, the artifact of greatest prestige and thus the most useful in power relations was cloth." Thus, in the cotton quipu, the Inca had a material that carried its own extraordinary message.

In every culture, there are special objects that stretch to regions far beyond the particular purpose for which they were intended. These objects sum up areas of meaning for which there may be no

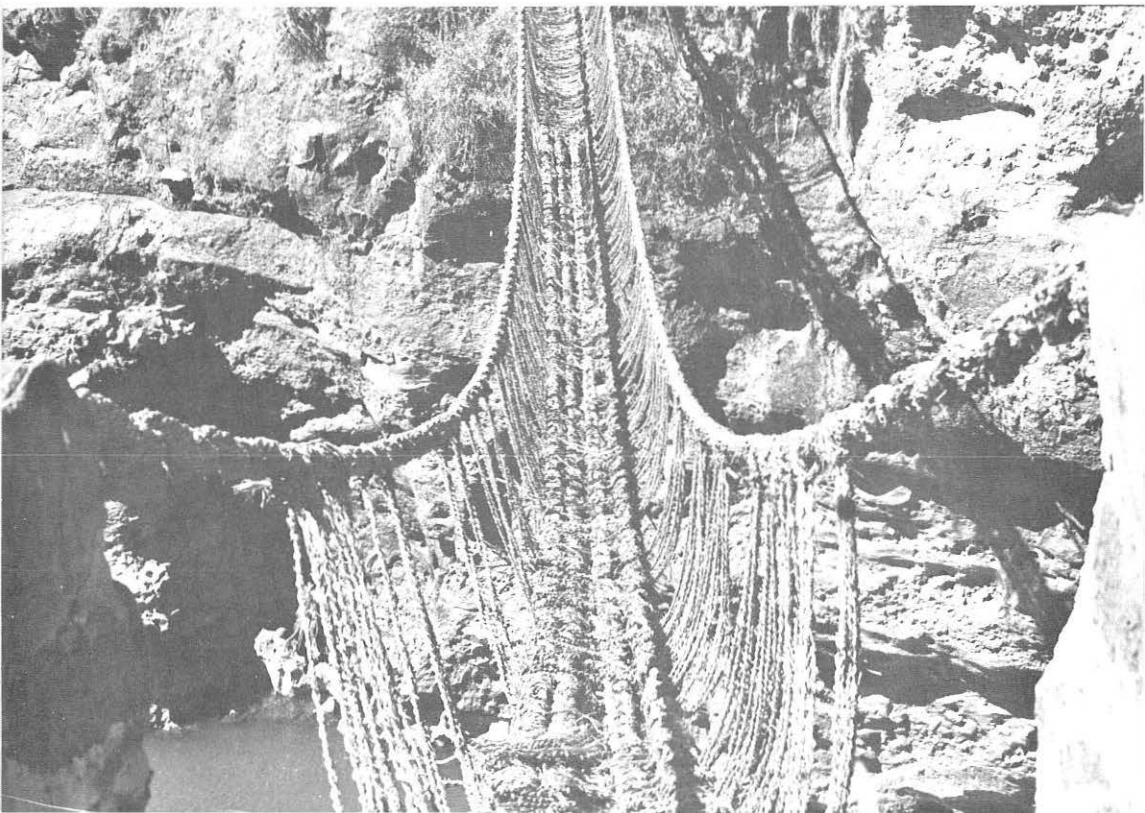


Figure 13. This quipu (AS33) is in the collection of the Peabody Museum of Archaeology and Ethnology, Harvard University. Photo by the authors.

verbal counterparts. They usually are common and replaceable, but they are not always inexpensive, as witness the American automobile. Sometimes they are keys to the culture for the outsider; for the insider, in particular children in the process of learning, they are indispensable cues. They may be fixed and rather permanent as the Medieval cathedral, or they can be impermanent and leave no trace, like an igloo.

We think that the quipu is such a special object. There is no way to prove this; but we can give a few examples that form part of the basis for our intuition, and thus conclude our essay. When the main cord of a quipu is freely held, one sees a smooth parabola bounding the tops of a series of vertical lines (Fig. 13). This shape is repeated in the hanging bridges of the Andes (Fig. 14). Suspended from the sides of rivers like giant quipus, these bridges were made, like quipus, from plant material and they are similar to quipus in construction. If the quipu as a special object is like a theme it should be repeated visually and thus underscored: the bridge is one of several instances that meets this requirement. Another requirement for being a special object is the ability of the object to express fundamental cultural notions. This is easy to show in the case of the quipu and the ceque system. The ceque system was the all important social organizational basis for the Inca state; it guided marriage, work, myth and ceremony, and so on (Zuidema, 1964). Its complexity is too great to detail here; however, it can be formally described as a division of the whole into 4 quarters, and within the quarters, a further division into 3 sets of 3. Using standard elements, a quipu expressing the formal structure of the ceque system can be constructed as follows:

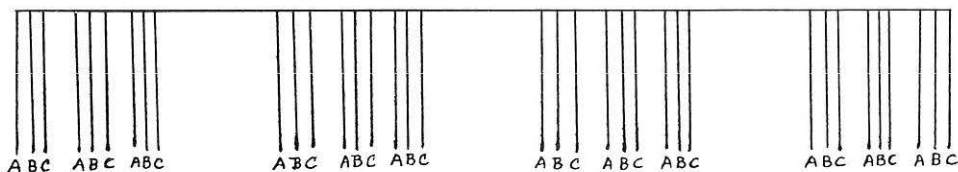


Figure 14. Until recently, this bridge hung over the Apurimac River in Peru. It was replaced by a metal bridge in 1968 (Gade, 1972). The photograph is here through the courtesy of Professor Daniel W. Gade and by permission from the *Annals of the Association of American Geographers*, 62, 1972.

1. References to actual quipus are followed by a letter and number designation. We identify all published quipus by this system: the letters refer to the author; the number to each quipu in chronological order of publication by author. For example, AS100 refers to the one hundredth quipu published by the authors of this article. For more details, see Ascher and Ascher, 1972.
2. Very many people in several countries cooperated with our efforts to locate and study quipus. Instead of thanking only a few people here, we will, instead, include everyone in a forthcoming final publication.
3. The Wenner-Gren Foundation for Anthropological Research provided partial financial support for our work.

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# An Orthographic Way of Writing English Prosody

Ernest M. Robson

An alphabetic process for cueing readers to speak the three dimensions of sound in speech has been constructed: fundamental frequency, duration, and intensity. A scanning model based on differences in the apparent levels of the three dimensions is presented. Considerations of the information in an alphabetic approach are discussed.

The two objectives of this paper are: to write prosodic levels with graphic symbols applicable to many spoken languages, and to formulate conversions of prosodic into stress levels. Discussions of the terms "acoustic level," "stress level," and "prosodic level" are required for clarification.






Prosody is a vague term. It is associated with systems of versification that may depend on "length" or duration of syllables (Greek),<sup>1</sup> or orderings of weak and strong stressed syllables (English); on rhyme and quasi-rhyme schemes; on stanza arrangements; on relations of syllables to musical notation, etc. All prosodic systems possess two characteristics: they are *written* rhythms of speech and their patterns are *systematic instructions by writers* to readers to speak in specified ways. It is essential to realize that "prosodic levels" must be written. Although every person does hear different levels of loudness or pitch in face-to-face conversation, a continuous symbol system of live speech cannot be fixed or analyzed in detail, or structured or programmed without memory storage of written or other recordings of language. Consequently, prosodic systems connect written and spoken language by graphic cues that identify and program selected units of speech rhythm. We will operate with graphic cues by modifying letters of the alphabet (Fig. 1A).

A written prosodic level is a graphic symbol that identifies a

perceptible acoustic level and instructs the reader to speak that level. Here, the graphic symbols are elevation, darkness, and length of letter. Since these graphic dimensions are built into the structure of letters, they produce orthographic symbols (Figs. 1A, 1B).

A level is ambiguous without a reference standard. The constant reference for perceiving variations of written prosodic levels is, simply, the normal appearance of letters. It is from this norm that readers judge whether vowels are elevated or lowered; whether all letters are squeezed or stretched out; or noticeably dark or faint. "Normal" appearance is the uniformity of letters consistent with a single style of typography or chirography.

"Acoustic levels" of speech are standard calibrated and instrumentally measured correlates of speech: fundamental frequency in Hz, sound pressure level in dynes, time duration and silences in centiseconds. These energy plateaus and time dimensions constitute the most universal physical features and coordinates of stress and prosodic levels. The prosodic correlates to acoustic levels are: perceived pitch for fundamental frequency, duration for time, perceived effort and force of speech for amplitude level and pauses for silences. "Speech power" may be used for convenience, in its loose sense as a perceptual term for "effort and force"; this only for the purpose of instruction to subjects.

A spoken prosodic level is vocalization of a perceived acoustic level in obedience to written instructions. The form of the instruction may be the  markings of the English department's "feet" which are simply stressed versus unstressed syllables. Other instructions may be diacritical markings such as Trager and Smith's 1, 2, 3, 4 markings for "pitch" levels, and , , ,  for four levels of stress.<sup>2</sup> During the eighteenth and nineteenth centuries prosodic instructions to speak "loudness" levels, pitch levels, time, and pause durations were written with musical notations as in the systems of Joshua Steele and Dr. Benjamin Rush.<sup>3</sup> Even though prosodic levels are "naturally" present in face-to-face speech, the vocal performance of prosodic systems as in singing or playing a musical instrument requires training, practice, and no audio-vocal disabilities.

Stress levels are impressions of loudness relative to the average

## DURATION

Reduced Vowels	A E I O U THE OF
Short	AEIOUWY
Normal	A E I O U W Y
Prolonged	

## SPEECH POWER LEVEL

Quiet unaccented speech (first amplitude level)	A E I O U W Y
Normal conversational level (second amplitude level)	A E I O U W Y
Maximum force and effort (third amplitude level)	A E I O U W Y

## FUNDAMENTAL PITCH

Lowest pitch—indicated by depressing the vowels	M <sub>I</sub> M M <sub>O</sub> M M <sub>AW</sub> M M <sub>EE</sub> M
Middle pitch—indicated by normal position on line	MIM MOM MAWM MEEM
Highest pitch—indicated by elevating the vowels	M <sup>I</sup> M M <sup>O</sup> M M <sup>AW</sup> M M <sup>EE</sup> M

## CUES FOR VOWEL PITCH MODULATION

Same vowel spoken with rising or falling pitch in periods  
controllable by speaker

### NORMAL SPEED

RISE                      FALL

A<sup>^</sup>

A<sub>^</sub>

E<sup>^</sup>

E<sub>^</sub>

I<sup>^</sup>

I<sub>^</sub>

O<sup>^</sup>

O<sub>^</sub>

U<sup>^</sup>

U<sub>^</sub>

### SLOW SPEED

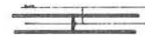
RISE                      FALL











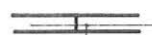










Figure 1A.

Prosody code for writing the English alphabet with structured letters that cue the reader to speak the acoustic levels of prosody.

## ENGLISH SPELLING

DO NOT ASK WHAT YOUR COUNTRY CAN  
DO FOR YOU, ASK WHAT YOU CAN DO  
FOR YOUR COUNTRY.

### AMPLITUDE

DO NOT ASK WHAT YOUR COUNTRY CAN  
DO FOR YOU ASK WHAT YOU CAN DO  
FOR YOUR COUNTRY.

### TIME

DO NOT ASK WHAT YOUR COUNTRY CAN DO FOR YOU  
ASK WHAT YOU CAN DO FOR YOUR  
COUNTRY.

### PITCH

DO NOT ASK WHAT YOUR COUNTRY  
CAN DO FOR YOU ASK WHAT YOU CAN  
DO FOR YOUR COUNTRY.

### AMPLITUDE+TIME+PITCH+PAUSES

DO NOT ASK WHAT YOUR COUNTRY CAN DO FOR YOU  
ASK WHAT YOU CAN DO FOR YOUR  
COUNTRY

Figure 1B.  
Prosodync cues written separately and combined.

STANDARD PHONETIC PORTRAYAL

mɛn ʒə sʌnlaɪt straɪks rɛndrəps

PHONETIC PORTRAYAL EMPLOYING PROSODYNES

AMPLITUDE

mɛn ʒə **sʌn**laɪt straɪks rɛndrəps

TIME

mɛn ʒə sʌnlaɪt straɪks r  ndrəps

PITCH

mɛn ʒə sʌnlaɪt straɪks rɛndrəps

PITCH, AMPLITUDE, TIME    ALL CUES PRESENT

mɛn ʒə **sʌn**laɪt **straɪks** r  ndrəps

Figure 1C.

Prosodynic writing of phonetic English. Notice adjustability of the independent dimensions in the prosodynic code.

loudness of an individual talker. They are auditory perceptions of undifferentiated vocal energy. It is assumed that native speakers of English who listen, repeatedly, to a single English sentence can identify and specify with markings, three to four levels of stress. The acoustic correlates of stress or loudness include all the acoustic correlates (fundamental frequency, amplitude, and time) of prosodic levels. It is not surprising that listeners will judge the relative loudness of synthesized speech according to the magnitude of the energy levels independent of which acoustic correlate was "traded" or substituted. In correspondence Pierre Delattre has stated, "It is true that amplitude and duration can affect our perception of intonation. (With speech synthesizers I can produce the impression of rises in pitch by over-emphasizing the duration as long as the

amplitude is not below normal).” It is the limited information potential of three to four stress levels per syllable in contrast to nine prosodic levels per syllable that indicates the richer speech pattern potential inherent in a prosodynamic cue system. This increase of speech information creates problems involved with the capabilities of speakers, the peculiarities of English, the training of speakers, and other questions beyond the scope of this paper.

Perception of acoustic levels will increase both with redundancy and with reduced or context free language.<sup>4</sup> Context free English occurs in specialized languages of poetry, advertising, song lyrics, nonsense syllables, short phrases in speech research, short sequences in foreign language teaching, speech therapy, deaf pedagogy, and any isolated short sequence of language of four to five syllables. Over the last forty years instrumental measurements of context reduced language show that listeners can recognize at least three levels of fundamental frequency, three levels of amplitude, and three periods of duration.<sup>5</sup>

The perceived acoustic dimensions and levels of prosody must be recorded in a readable form to be available for use and understanding by speech and language specialists in many areas. If they are presented solely by spectrographic or other instrumental displays, both cost and convenience impose severe limitations. The kind of notation becomes important for teaching and creative uses. Diacritical notations—even when restricted to a few suprasegmentals such as juncture, intonation, and stress—have shown serious deficiencies.<sup>6</sup>

#### *Integrating Prosodic Levels with the English Alphabet*

Alphabetic cues which instruct readers to speak prosodic levels specified by the *length, height, and darkness* of letters seem to make several contributions. First, they graphically denote with the same symbol system (letters) all the acoustic dimensions of prosody carried by phonemes, syllables, words, phrases, contours, and sentence envelopes. Secondly, the graphic aspects of the script enable readers to scan stress patterns and visualize acoustic levels. This kind of writing is, literally, a display of transitions from perceived acoustic to stress levels; and the converse. Heights and slopes of levels are essential components of these displays as in spectrographs

of fundamental pitch or intonation.<sup>7</sup> A third asset of alphabetic cues is their capacity to show variations of intensity and duration of consonants, variations that modify stress.<sup>8</sup> Fourthly, the change in fundamental frequency of a vowel synchronized with intensity and duration variations can be written as “pitch modulation” cues (Fig. 1B). Fifth, a prosodic expression of the semantic intent of the writer can be written. Alphabetic cues which instruct readers to speak prosodic levels specified by the length, height, and darkness of letters are called “prosodynes” (Fig. 1C).<sup>9</sup>

In linguistics the “schwa” is now termed a reduced vowel. When we scan spectrographs, visually, a reduced phoneme appears as a trace. We shall use “reduced” and “trace” interchangeably. The trace warrants special consideration. There is a physical reason for attaching a value of 1 to the reduced vowel or syllable. The reduced vowel is essential in prosody because it operates as a cue for continuity or discontinuity of speech. Its faint and rapid glottal rumble puts sharp dips into the acoustic rhythm of English. Reduction obliterates distinctive features and minimizes the quality in levels of pitch and loudness close to the thresholds of perception (i.e., to no quality). Therefore the trace is allocated no perceived pitch or amplitude values. Yet a reduced vowel exists. It consumes noticeable time. Consequently, the reduced vowel or syllable has been designed to be singular (Figure 2). It is labeled “1” among the numbers given to prosodic levels. This cue is written  $A \rightarrow o$   $T_1$   $P \rightarrow o$  to show pitch and amplitude approaching 0 in perceptive value. The information of the trace plus pitch modulation cues considerably increases the potential of prosodynic print.

#### *Scanning with Prosodynic Levels*

A prosodic number is the sum of numbers assigned to each perceived acoustic level of pitch, force, and duration. The largest prosodic number for a vowel equals the sum of the three numbers denoting the highest level of perceived pitch 3, the most powerful amplitude level 3, and the longest time extension 3. The sum is 9. This will be the most stressed vowel or syllable. The smallest sum of level numbers in a vowel will be 1 for the singular trace syllable or vowel. This is the least stressed syllable. The larger the prosodic number, the greater the amount of acoustic energy and stress value (Fig. 3).

All T faster rate of speech

3rd Amp.

2nd Amp.

1st Amp.

Reduced

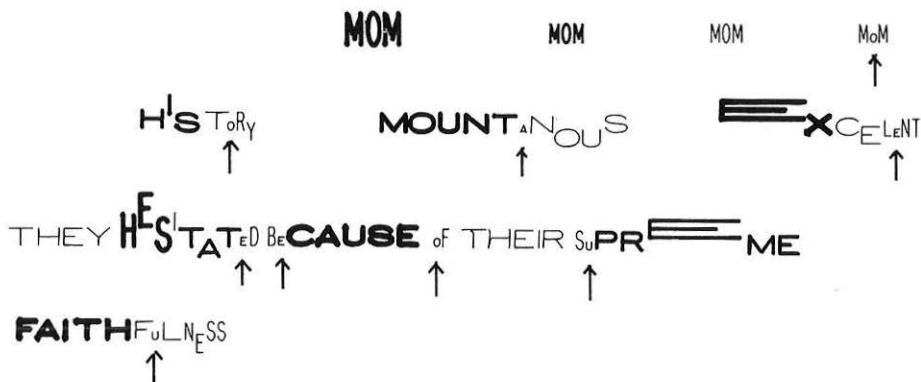


Figure 2.

The graphic cue for reduced vowels or syllables. Although this “schwa” cue is needed, arithmetically, to specify four stress levels and is a readable cue, speakers seldom articulate a reduced A—o, T<sub>1</sub> P—o vowel differently from an A<sub>1</sub> T<sub>1</sub> P<sub>1</sub>. See note under Figure 5 for arithmetical operations that support a value of 1 for reduced vowels.

Figure 3.

Qualitative associations between numbers of stress levels and numbers of prosodic levels.

	Stress Level	Stress Quality	Amp. T P Prosodic Number	Prosodic Quality
<b>A</b>	1	Minimum Detectability	0 + 1 + 0 = 1	Reduced
<b>C<sub>A</sub><sup>N</sup></b>	1	Inconspicuous	1 + 1 + 1 = 3	Weak
<b>T<sub>E</sub><sup>S</sup>T</b>	2	Inconspicuous	1 + 2 + 1 = 4	Weak
<b>B<sup>E</sup></b>	2	Between inconspicuousness and prominence	1 + 1 + 3 = 5	Between Weak and Rich
<b>D<sup>A</sup>NCE</b>	3	Prominent	2 + 1 + 3 = 6	Rich
<b>C<sup>O</sup>N</b>	3	Prominent	2 + 2 + 3 = 7	Rich
<b>O<sup>N</sup>E</b>	4	Most Conspicuous	3 + 2 + 3 = 8	Powerful
<b>W<sup>I</sup>L<sup>D</sup></b>	4	Most Conspicuous	3 + 3 + 3 = 9	Powerful
<b>B<sup>A</sup>L<sup>L</sup></b>	4	Most Conspicuous	3 + 3 + 3 = 9+	Rich and Powerful

**D<sup>A</sup>NCE** **C<sup>O</sup>N**<sub>T</sub>**E**<sub>S</sub>**T**

**C<sub>A</sub><sup>N</sup>****B<sup>E</sup>** **O<sup>N</sup>E** **W<sup>I</sup>L<sup>D</sup>** **B<sup>A</sup>L<sup>L</sup>**

Stress levels here are synonymous with “loudness” levels. These levels are functions of objective and subjective components. The objective parameters are three measurable “acoustic levels”; the subjective factors are three prosodic levels each “a *perceived* acoustic level.” Prosodynamic levels are both written and spoken. They can be assessed as contributors to “stress” or loudness. It is understood that listeners may concentrate on stress at one time, and on the prosodic levels that produce stress or loudness at another. Targets of attention are involved with training. Although “stress” or “loudness” are produced by many non-acoustic influences, here, on a phonological basis stress is the impression of gross undifferentiated loudness carried by the longitudinal waves of sound. Figure 4 shows how many distributions of prosodic levels may produce the same stress level and why “trading” in prosodic levels occurs.<sup>10</sup> Writers of prosodynamic print continuously operate with this kind of trading.

When we scan the speech rhythms of English with these numerical measures, we gain insight by understanding the problems of a writer intent on writing phrases and sentences with prosodynamic script. Here is where judgments enter. The maximum number of gross stress levels amounts to 4. It is easier to first select a stress pattern of 4 levels than to first think of 46 prosodic levels. Once the stress pattern is structured, then prosodic levels fall into shape.

A simple arithmetic can convert prosodic into stress levels. We have represented the perceived pitch, amplitude, and time levels by the numbers 1, 2, 3, ranging from small to large. *Then, to determine the stress level of any particular vowel or syllable with respect to its neighbor take the difference between the sums of the numbers assigned for pitch, perceived amplitude, or time and divide by two.* Thus a difference of two prosodic numbers on two syllables will give one stress level difference, etc. Since the smallest prosodic number is 1 for the trace and the largest is 9, the highest stress level is  $\frac{9-1}{2}$  or 4. In English, 4 has been accepted as a maximum stress level by many workers.<sup>11</sup> Divisions by two are supported by experiments. These show that whenever two prosodic levels of two neighboring syllables—such as pitch and duration, or pitch and perceived amplitude, or perceived amplitude and duration—increases in the same

PROSODIC FREEDOM OF THE WRITER

n = the sum of numbers assigned to levels of perceived pitch, amplitude and duration. These are prosodic numbers specified for a specific vowel or syllable by the writer.

Column totals = summations of *number of ways* of writing a prosodic number. Each of these permutations may be considered a "prosodic state."

$\frac{(n=9)}{A+P+T}$	$\frac{(n=8)}{A+P+T}$	$\frac{(n=7)}{A+P+T}$	$\frac{(n=6)}{A+P+T}$	$\frac{(n=5)}{A+P+T}$	$\frac{(n=4)}{A+P+T}$	$\frac{(n=3)}{A+P+T}$
$\frac{3+3+3}{1}$	$\frac{2+3+3}{3+2+3}$	$\frac{1+3+3}{3+1+3}$	$\frac{2+2+2}{3+2+1}$	$\frac{1+3+1}{3+1+1}$	$\frac{2+1+1}{1+1+2}$	$\frac{1+1+1}{3}$
	$\frac{3+3+2}{3}$	$\frac{3+3+1}{3+2+2}$	$\frac{2+3+1}{3+1+2}$	$\frac{1+1+3}{2+2+1}$	$\frac{1+2+1}{3}$	
		$\frac{2+3+2}{2+2+3}$	$\frac{1+3+2}{1+2+3}$	$\frac{2+1+2}{1+2+2}$		
		$\frac{2+2+3}{6}$	$\frac{1+2+3}{2+1+3}$	$\frac{2+1+2}{6}$		
			$\frac{2+1+3}{7}$			

1 + 3 + 6 + 7 + 6 + 3 + 1 = 27 = number of choices for the writer of non-modulated syllables

$\frac{(n=9)}{A+PP+T}$	$\frac{(n=8)}{A+PP+T}$	$\frac{(n=7)}{A+PP+T}$	$\frac{(n=6)}{A+PP+T}$	$\frac{(n=5)}{A+PP+T}$	$\frac{(n=4)}{A+PP+T}$	$\frac{(n=3)}{A+PP+T}$
$\frac{3+3}{1}$	$\frac{3+3}{3+2}$	$\frac{3+2}{2+3}$	$\frac{3+1}{2+2}$	$\frac{2+1}{1+2}$	$\frac{1+1}{1}$	Nothing
	$\frac{+3}{+3}$	$\frac{+2}{+2}$	$\frac{+2}{+2}$	$\frac{+2}{+2}$	$\frac{+2}{+3}$	because
	$\frac{2+3}{3}$	$\frac{2+2}{1+3}$	$\frac{1+3}{2+1}$	$\frac{1+1}{3}$		fast
		$\frac{2+2}{3+1}$	$\frac{1+2}{1+2}$			duration is
		$\frac{2+3}{3+1}$	$\frac{1+3}{1+2}$			impossible
		$\frac{3+3}{5}$	$\frac{2+3}{5}$			for pitch
						modulation

1 + 3 + 5 + 5 + 3 + 1 = 18 = number of choices for the writer of modulated syllables

Non-modulated states = 27

Modulated states = 18

Trace syllable = 1

46 = Total Prosodynic States (choices) per syllable

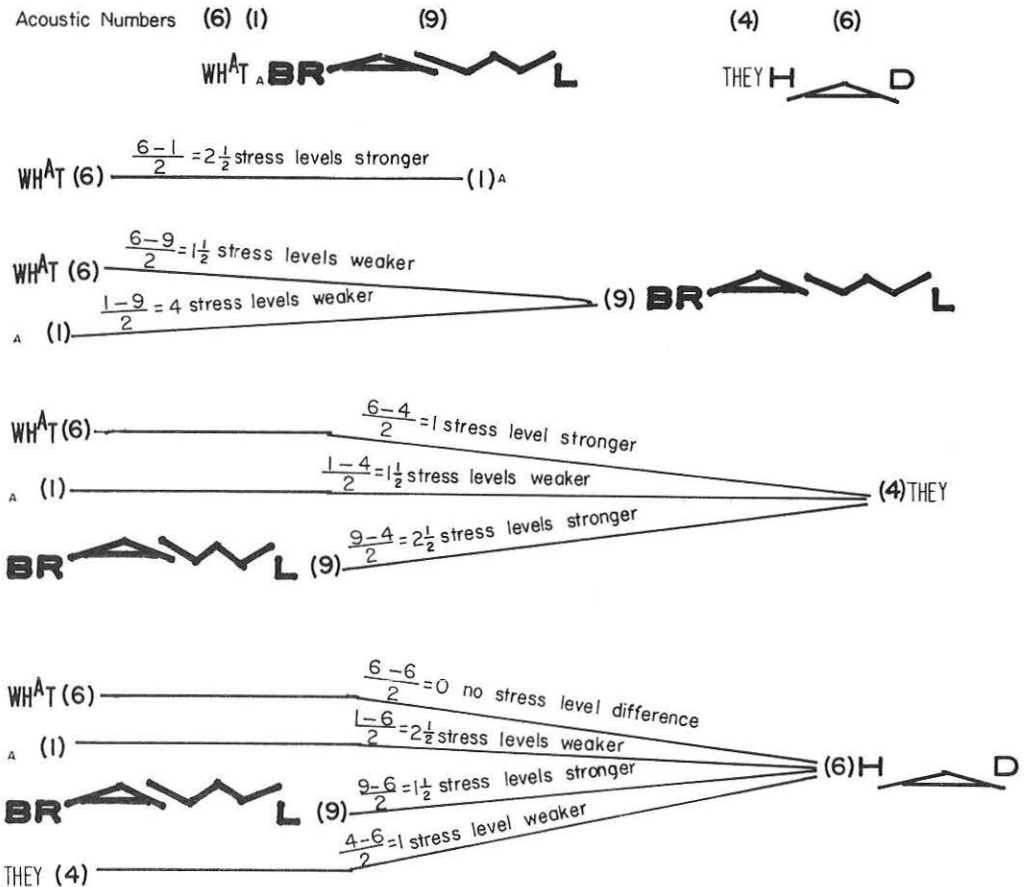
Figure 4.

"Prosodic freedom" of the writer or the number of choices for writing syllables with different prosodic numbers. The shape of this matrix is somewhat similar to the normal distribution curve. Exercise of this "freedom" is reduced by all the constraints of English except in poetry, language research, and other special uses.

direction, then at least one stress level difference is observed 90% of the time.<sup>12</sup> This stress difference between two syllables implies that levels of their third prosodic dimension remain constant. A graphic portrayal of how differences in prosodic levels within a sentence can generate 4 stress levels is presented in Figure 5.

Figure 5.

Converting prosodic numbers by difference into relative stress levels for pairs of monosyllabic words in a sentence. Suppose we had no trace value of 1. Then, we could not calculate 4 levels of stress as a maximum difference between a pair of most and least stressed syllables; i.e.,  $\frac{9-1}{2} = 4$ . Yet, we know by experiment that 4 levels of stress are perceivable in non-contextual English. This is the rationale for attaching "1" to reduced vowels. It is an arithmetic device for satisfying experimental values.



When we deal with prosodic numbers we consider sums of numbers assigned to perceived levels. Prosodic states operate with permutations of these numbers. A prosodic state is any combination of three levels of perceived pitch, amplitude, and time. Since each of these three parameters has three levels, the total of their permutations =  $3^3 = 27$ . This applies to all non-modulated prosodic states. The number of modulated states would equal another 27 were it not impossible for the modulated pitch and force effort cues to work in fast time (Fig. 1A). With medium and slow durations there are  $2 \times 3 \times 3 = 18$  modulated prosodic states (Fig. 4). Add to these unity for the singular reduced vowel. The final sum is  $27 + 18 + 1 = 46$ . Figure 4 also makes it evident that extremely high or low stressed vowels demand the fewest prosodic decisions by the writer while medium stressed vowels maximize the number of decisions.

#### *Discussion of Information in Graphic Design*

Prosody in print carries more of English speech into print than either diacritical marks or standard English orthography. Its information is primarily graphic. One might say that prosody is less visible speech than the visible intentions of speech; particularly, the writer's intentions. Because the subjective intentions of the speaker determine emphasis, prominence, and the other information of prosody, clarification of a writer's prosodic intention may reveal substantial amounts of information.

When we look at written language from a strictly graphic point of view, the cues of prosody in print appear to exploit the limits of distortion of a letter without destroying its recognizability. Each variation of shape of a letter may be counted as a choice in the structure of that letter. Accordingly, the number of choices within the limits of recognizability is a kind of "graphic information." It is this sort of graphic information which is the visual essence of these cues.

The print is designed to look as it sounds. This is accomplished by selecting physical features that occur in both the spoken and written symbols of prosody: up-down markings identify up-down pitch; amount of blackness represents amount of vocal force and effort; extensions of length identify extensions of time; blank white

space stands for silence of pauses. These associations are structured so that foreign readers may more easily identify the prosody of a second language. This isomorphism can be assessed by comparative tests with diacritical symbols.

Prosodynamic dimensions are spatially independent. The occurrence or non-occurrence of one prosodynamic cue in no way affects the occurrence of any other cue. As a result displays of a single letter's cues for pitch, apparent amplitude, and time do not interfere with perceptions of contours of intonation or loudness. Spatial independence is an important component of graphic design. Its opposite, conjugality, causes confusion; e.g., when the height dimension of size as a cue for loudness cannot be separated from the elevation of vowels as a cue for pitch in intonation contours.

It is well known that the consonants contribute more than the vowels to our recognition of both aural and written language. The meaning of the sentence below can be read more easily from consonants than from vowels:

\*A\*E\* \*I\*\* \*\*I\*E \*I\* \*A\*I\*\* \*A\*

J\*M\*S W\*LL DR \*V\* H\*S R \*C\*NG C\*R

This cue system maintains consonantal intelligibility by keeping consonants on the same line. This uniformity fixes the eye on a graphic standard of reference. Reference standards increase the information of stimuli.<sup>13</sup> It is the vowels that carry most of the information in this system. Here, vowels are the principal cues for pitch because vowel sounds are the prime source of perceptions of frequency and intonation in English.

Prosodynamic print instructs readers to articulate consonants with different efforts and durations, along with vowels at varying pitch, intensity, and durations. These orthographic contrasts enable readers to visualize transitions from prosodic levels to stress levels at a glance. Stress patterns are in the orthography.

This study observes at least four criteria for increasing the information of notations, the power of written language symbols where "power" means the number of events a symbol might identify:

1. The smaller the linguistic units, the more information they carry; i.e., alphabets give more information than syllabaries.
2. Spatial independence of cues.
3. Multi-dimensionality in contrast to single dimensional cues.
4. A graphic reference standard for perceptual judgment.

Finally, it should be noted that prosodynic print has been used for speech therapy on two patients<sup>14</sup> and in creative poetry.<sup>15</sup> A better understanding of the basic processes involved and on their application calls for continued testing; e.g., on the model for converting prosodic levels into speech levels.

### *Summary*

An orthographic technique for writing English prosody has been developed by distortions of length of letters, differences in darkness, and the elevations of letters, and by varying extensions of white space between words. The three perceived dimensions of prosody (pitch, apparent amplitude, and time) are *numerically* matched by three *independent* graphic dimensions (elevation, darkness, and length). The independence of the discrete graphic symbols are at least as independent as the symbols in the continuous oral system.

1. W. W. Goodwin & C. P. Gulick. *Greek Grammar* (Waltham, Mass., 1958), p. 26. The Greeks attached duration or length to their vowels as a function of the number of consonants that followed the vowel. This was one factor in scanning Greek poetry. Clearly, numerous scanning systems can be written dependent on cue instruction to emphasize this or that cue component of a language.
2. G. L. Trager and H. L. Smith. *An Outline of English Structure* (Washington, 1957), p. 49.
3. John Walker. *On Pronunciation of Proper Names* (Philadelphia, 1808), p. 306.  
Joshua Steele. *Towards Establishing the Melody and Measure of Speech to be Expressed and Perpetuated by Peculiar Symbols* (London, 1781), pp. 24, 189-190.  
H. A. Gleason. *An Introduction to Descriptive Linguistics*, rev. ed. (New York, 1961), p. 45.  
Ernest M. Robson. *The Orchestra of the Language* (New York, 1959), p. 44.
4. Naom Chomsky. *Syntactic Structures* (The Hague, 1957), p. 38; note on prosodic compensation in reading "non-grammatical strings."  
Phillip Lieberman. *Intonation, Perception and Language* (Cambridge, Mass., 1967), p. 166. See also reference to "degrees of stress on isolated words," p. 182.

5. At least three levels of perceived pitch (frequently 4 levels) have been observed by many linguists and phoneticians (Lieberman, pp. 171-195). Short duration intervals range from 0.04 sec. to 0.12 sec.; average durations from 0.20 sec. to 0.28 sec.; long durations from 0.40 sec. to 0.48 sec.; SD=0.041 sec. For measurements of these periods which give a mean ratio 3:1 = long duration/short duration, see reports by:

G. E. Peterson & I. Lehiste. "Duration of Syllable Nuclei in English," *Jrn. Ac. Soc. Amer.*, xxxii, No. 6, 1960, p. 702.

D. B. Fry. "Duration and Intensity as Physical Correlates of Linguistic Stress," *Jrn. Ac. Soc. Amer.*, xxvii, No. 4, 1955, p. 768.

J. N. Pickett & I. Pollack. "Intelligibility of Excerpts from Fluent Speech," *Lang. and Speech*, vi, 1963, July-Sept., pp. 156-159.

George A. Miller. *Language and Communication* (New York, 1951), p. 74.

A. H. House. "On Vowel Duration in English," *Jrn. Ac. Soc. Amer.*, xxxiii, 1961, No. 9, pp. 1174-1178.

Pierre Delattre. "A Comparison of Syllable Length Conditioning Among Languages," *Sonderdruck aus IRAL*, iv, 3/1966, pp. 186-196.

An amplitude difference of 9db between two syllables in the same linguistic environment equals one loudness level in short English. See the phon scale of loudness level in Harvey Fletcher, *Speech and Hearing* (New York, 1958), pp. 177-194 for tonal loudness levels, and pp. 76-78 for ranges of speech power over 60db from very quiet to extremely loud speech. This range is broad enough to cover three loudness levels in a continuous flow of talk that varies between soft spoken and shouted words. These intensity level differences are standard psycho-acoustic knowledge. That the wide db range of talk does not frequently occur in conversation excludes neither its possible occurrence nor the desirability to be able to identify it by notation.

6. Claude Wise. *Applied Phonetics* (Englewood Cliffs, N. J., 1951), pp. 182, 397.

Pierre Delattre. "Comparing the Prosodic Features of English, German, Spanish, and French," *Sonderdruck aus IRAL* Vol. 1, 3/1963, p. 194. Delattre has shown, convincingly, the need for graphic representation of suprasegmental information and the inadequacy of numerical identification of levels as vocal instructions. An adequate notation should reach visual-minded people. That this is not a trivial consideration is substantiated by the role of geometry in the history of mathematics: Raymond L. Wilder. *Evolution of Mathematical Concepts* (New York, 1968), pp. 106-109.

Ralph N. Haber. "How we remember What We See," *Scientific American*, 5/1970, pp. 104-112.

7. Ilse Lehiste & Gordon Peterson, "Some Basic Considerations in the Analysis of Intonation," *Jrn. Ac. Soc. Amer.*, xxxiii, No. 4, 4/1961, pp. 420-421.

A. E. Rosenberg. "Effect of Pitch Averaging on the Quality of Natural Vowels," *Jrn. Ac. Soc. Amer.*, xlv, No. 6, 12/1961, pp. 1593-1594.

8. Pierre Delattre. "A Comparison of Syllable Length Conditioning Among Languages," *Sonderdruck aus IRAL*, iv, 3/1966, pp. 186-196.

P. Denes. "On Statistics of Spoken English," *Jrn. Ac. Soc. Amer.*, xxxv, No. 6/1963, p. 898.

9. Originally prosodynes were presented to the Phonetics, Linguistic, and Voice Science Interest Group in New York City at the December 1965 meeting of the SAA, under the name of "Intonemes." In 1967 Pierre Delattre wrote a letter

suggesting the term "prosodeme." I modified "prosodeme" to "prosodyne" because of the association of energy with "dyne" and energy levels of prosody.

10. Phillip Lieberman. "Some Acoustic Correlates of Word Stress in American English," *Jrn. Ac. Soc. Amer.*, xxxii, No. 4, 1960, pp. 451-454.

Fry, pp. 765-768.

11. G. L. Trager & H. L. Smith. *Outline of English Structure* (Norman, Oklahoma, 1951). Daniel Jones has specified several stress levels for "sense groups" of short English; only two stress levels for long conversation. Evidently, Phillip Lieberman agrees with Jones (*Intonation, Perception and Language*, p. 182). Further support of three to four stress levels in short English comes indirectly from the need to specify six different db levels on the newer sonograph displays of speech spectrographs. The classic loudness scales (Fletcher, Stevens, Garner) also suggest three to four levels of "loudness" as range limits.

12. Lieberman, pp. 453-458; Fry, p. 767.

13. I. Pollack. "Information of Elementary Auditory Displays," *Jrn. Ac. Soc. Amer.*, xxv, July 1953, pp. 765-769.

14. "Intonemic Orthography in Speech Therapy" presented April 1967 to the Pennsylvania Speech and Hearing Association conference in Pittsburgh. Therapy was conducted by Anne Highland at the Speech and Hearing Clinic, University of Pennsylvania Hospital, Philadelphia.

15. Ernest M. Robson. *Transwhichics* (Chester Springs, Pa., 1970).

## RTA—The Transit Network?

Dick Feagler

The Regional Transit Authority just paid a design firm \$25,000 for a new symbol for itself. Here it is:



Now then, if you let your fingers do the walking through the Yellow Pages, you will find a symbol for the Radio Corporation of America. Here it is:



Some people claim there is a similarity.

I don't, you understand. . . . I want to make it clear that I don't believe for a minute that F. Eugene Smith and Associates who designed the RTA symbol stole it from RCA.

After all, F. Eugene Smith didn't draw anything you can't find in a can of alphabet soup.

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This is a democracy, you know. F. Eugene Smith has as much right to use the alphabet as any kindergarten kid does. And certainly his choice of the letter "R" to stand for Regional, the letter "T" to stand for Transit, and finally the letter "A" to stand for Authority reflect a great deal of thought on his part.

He certainly has not sacrificed clarity for style.

A little question does occur to me though.

Why, when you can't get a loop bus at 7 p.m., when people are complaining about stalled CTS Rapids, when many county suburbs have no bus service at all. . . .

Why would you spend the first chunk of the money the citizens voted you by paying some artiste to draw three letters?

And deciding that they should be colored red and orange and figuring out what color busses should be painted.

Haven't they got anybody over at RTA who can print? Isn't there some old guy around with a paint bucket who paints the gender on bathroom doors who could have taken five minutes of his time with a black crayola and figured out a way to print the letters: RTA?

"We felt there needed to be a new identity," said Jay L. Hanna of RTA.

I know what he means.

Just yesterday, I was standing at a bus stop and the guy standing next to me was twitching and sweating and obviously very nervous. I asked him what was the matter.

"What if the bus comes along and I don't recognize it," he said.

"What if it stops here and I don't get on it. What if it leaves and I'm still standing here because I couldn't identify it as a bus?"

"Don't worry about it," I said. "They are big, boxy things, buses are. They have a lot of seats and chrome poles in them. You'll know one when you see it because a guy in a blue cap will be driving it. The door will go hisssss when it opens."

"You're talking about the old-fashioned buses," he shrieked. "I'm worried about the RTA buses. How will I know one of them when I see it. Suppose I try to board an RCA television repair truck by mistake? What will happen to me?"

With this kind of fear in the community, I suppose we should be thankful that the RTA people shelled out \$25,000 for a bus monogram.

Excerpted with kind permission from *The Cleveland Press*, Thursday, September 25, 1975, p. 2.

## Correspondence

*The editors welcome comments on articles, reviews, and letters that have appeared in past numbers. Communications should be addressed to the Editor, c/o The Cleveland Museum of Art, Cleveland, OH USA 44106.*

To the Editor:

Has anybody wondered why half of our roman capitals are oriented toward the right? Eleven of them are symmetrical, plus the J, which is really just an I with a tail. The Z stops the flow of the alphabet by being the only one that looks to the left. The other thirteen look to the right. What I am really asking is: What makes us see those thirteen shapes as looking the other way? In school we were taught the shapes and meanings of these letters; but nobody told us that B and C and D look to the right. If it is a tradition, how is it transmitted?

You may be quick to suggest that we write and read from the left to the right, and therefore the letters are seen to be oriented in the direction of the movement. But who told us that Z is an exception? And then there are the numerals. They, too, are written from the left to the right, but six of the ten are oriented toward the left. If the 1 is written without a serif, three are symmetrical, and only the 6 looks toward the right. Is there something in the nature of these shapes that determines direction? In letters like B, D, E, L, R the vertical main stem is written first, and the rest is secondary matter that hangs out toward the right. In 4, 7, 9 the opposite is true, and they do look to the left. Is it a question of openness versus closedness? Letters like E, F, K, P have a solid back wall and open out toward the front, as the human body does when viewed in profile. But why should S and N be seen as turned toward the right, and the Z the other way?

In order to test some of these hypotheses one could construct meaningless figures containing one of these features and ask subjects in which direction, if any, they seem to be oriented.

Note here that a change of direction transforms the shape. Perceive a 3 as the bosomy part of a B, and the change from concavity to convexity creates a totally new figure. See the 6 as an aquiline nose turned westward, and the familiar numeral is gone. Note further that the same is true for other visual objects. If you read a brush from the bristles toward the wooden back instead of the other way around, you obtain an alien

object with flowing hair and a flat profile. And rarely does one read a bottle from the neck down as though it were a baseball bat. So we are discovering here a perceptual problem of some general relevance concerning the dynamics of shape. Any reactions?

Rudolf Arnheim

University of Michigan, Tappan Hall, Ann Arbor.

To the Editor:

I read Richard L. Venezky's "Curious Role of Letternames in Reading Instruction," (IX [Winter 1975], 7-23) with great interest.

I entirely agree with Venezky's criticism of letternames in English, and in view of the fact that a few languages (e.g., Bulgarian, Esperanto, and Turkish) have all their letters named according to initial acrophony, why should we not reform our ef, aitch, el, em, en, ah, es—to ah, le, me, ne, ha, and se? Apart from the educational argument, considerations of avoiding some annoying little problems of international miscomprehension in dictating names and addresses over the telephone in Europe arise due to English R having a name homophonous with French, German, etc., A.

Concerning historical proposals of reforming letternames, I would like to add another later reference to Venezky's citation of Hart, J. P. Bonet's *Reduccion de las letras, y arte para enseñar a ablar los mudos* (Madrid, 1620)—which appeared translated by H. N. Dixon and published in London in 1890 as *Simplification of the Letters of the Alphabet and Method of Teaching Deaf-Mutes to Speak*—has as chapter ten "The reason why children are so long in learning to read; and a demonstration that the cause of their difficulty lies in the names given to the letters by their teachers." Bonet also had the educationally useful idea that letterforms are similar to lipshapes made when pronouncing the sound represented by the letter. This idea, on which I have worked for some years and for which I have found fifteen authorities, is the subject of a paper I am preparing.

I would also like to offer some further and amusing examples of edible letters: "Now when the time for reading came to him, the cleric went to a certain prophet who abode in the land, to ask him when the boy ought to begin. When the prophet had scanned the sky, he said: 'Write an alphabet for him, now.' The alphabet was written in a cake. And Colomb Cille consumed the cake. . . . Not long thereafter . . . the man of grace Colomb Cille, chanted the psalm . . . and yet he had not read till then aught save an alphabet. God's name and Colomb Cille's were magnified

by that miracle.” Whitely Stokes (ed.), *Lives of the Saints from the Book of Lismore*, Oxford, 1890, pp. 172f. On page 303 Stokes gives a reference to Henri Gaidoz *Les gateaux alphabétiques* (Paris, 1886) and cites Horace, *Sat. I 25* “*ut pueris olim dant crustula blandi| Doctores, elementa velint ut discereprima.*” Franz Dornseiff in his *Das Alphabet in Mystik und Magie* (Teubner, Berlin, 1925, 2nd. ed.) gives the same references plus one to Erasmus; to Paul Barth *Geschichte der Erziehung*, 1911, 236; to Rabelais; to Goldsmith, *Vicar of Wakefield*; to Smollett, *Humphrey Clinker*; and other.

Peter Mayer  
Visual Communication Lecturer  
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# Résumé des Articles

Traduction: Fernand Baudin

Quelles sont les caractéristiques propres de l'alphabet? I. Desiderata, *par W. C. Watt*  
Jusqu'à un certain point, un alphabet peut être assimilé à un langage ayant une grammaire propre. Toutefois, étant donné qu'un tel langage est susceptible de recevoir plusieurs grammaires différentes, il s'agit, si l'on prend l'analogie linguistique au sérieux, de trouver les critères qui permettront de décider laquelle de ces grammaires est la meilleure. Si l'on nous accorde que les utilisateurs d'un alphabet en ont une image mentale cohérente, les choses deviennent assez simples: la meilleure grammaire est celle qui se rapproche davantage de ce que les gens ont en tête. L'article propose deux analyses linguistiques de l'alphabet, très poussées, tendant à illustrer les aspects psychologiques de la question. Conclusion: il faut pousser plus loin cette analyse.

Le quippu, langage visuel  
*par Marcia Ascher et Robert Ascher*

Les Incas sont souvent considérés comme une civilisation sans écriture. C'est oublier que l'écriture est plus qu'un système de sons associés à des objets familiers. Les supports des messages Incas étaient composés de cordelettes de coton appelées quippus. L'article est fondé sur un examen de la plupart des quippus conservés dans les musées de trois continents et tend à expliquer comment les éléments matériels des quippus ont été combinés en vue de former des structures symboliques capables de représenter des nombres, des objets de N dimensions, les degrés d'une hiérarchie. Il aborde aussi les rapports qui pouvaient exister entre le quippu et la civilisation notamment: (1) quant au sens que pouvait avoir le coton en lui-même aux yeux des Incas; (2) quant au sens que le quippu pouvait avoir dans la

civilisation Inca en dehors du domaine de la communication proprement dite; (3) quant à la raison d'être de l'écriture dans une civilisation ancienne.

La notation alphabétique de la prosodie anglaise *par Ernest M. Robson*

Il s'agit d'une notation alphabétique susceptible d'aider les lecteurs à émettre les trois dimensions de la parole articulée: fréquence, durée et volume. Un modèle de lecture est proposé indiquant les différents niveaux dans chacune des trois dimensions. L'auteur examine les divers aspects de ce type de notation.

# Kurzfassung der Beiträge

Übersetzung: Dirk Wendt

Welche Charakterisierung des Alphabets ist angemessen? I. Desiderata, von *W. C. Watt*

In gewissem Sinne kann ein Alphabet als eine "Sprache" angesehen und durch eine "Grammatik" beschrieben werden. Da aber für jede solche Sprache viele verschiedene Grammatiken möglich sind, muß man Kriterien suchen, nach denen man beurteilen kann, welche "richtige" Grammatik die beste ist, wenn man diese "linguistische" Analogie ernst nehmen will. Wenn wir davon ausgehen, daß die Benutzer des Alphabets irgendeine geistige Repräsentation des Alphabets besitzen, dann ist die Grundlage dieser Beurteilung klar: diejenige Grammatik ist am besten, die am besten das System annähert, das die Leute in ihren Köpfen haben. Um zu zeigen, welche Rolle psychologische Erkenntnisse bei dieser Frage spielen, werden zwei raffinierte "linguistische" Analysen des Alphabets untersucht; die Schlußfolgerung ist, daß noch eine weitere Analyse notwendig sei.

Der Quipu als sichtbare Sprache von *Marcia Ascher und Robert Ascher*

Die Inkas werden oft eine Zivilisation "ohne Schrift" bezeichnet. Aber Schrift ist mehr als eine Aufzeichnung der Sprache auf den vertrauten Materialien. Das Medium der Inkas waren Gegenstände aus Baumwollschnüren, die Quipus genannt werden. Diese Einführung in den Quipu basiert auf einer neueren Untersuchung der in der Welt bekannten Quipus, die jetzt über drei Kontinente verstreut sind, und konzentriert sich darauf, was wir annehmen, daß das System sei, nach dem die physischen Elemente des Quipus kombiniert wurden, um eine symbolische Struktur zu bilden, d.h. die Wiedergabe von Zahlen, die Repräsentation N-dimensionaler Matrizen, und hierarchische

Konfigurationen. Eine Diskussion der Verbindungen zwischen Quipu und Zivilisation geht auf folgende Punkte ein: (1) Baumwolle als ein Material, das für den Inka eine Botschaft eigener Art darstellte; (2) Entsprechungen des Quipu in Bereichen der Inka-Zivilisation außerhalb der Medien; und (3) der Zweck der Schrift in frühen Zivilisationen.

Eine Orthographie für englisches Versmaß (Prosodie) von *Ernest M. Robson*

Es wurde ein alphabetisches Verfahren entwickelt, das Lesern Hinweise zum Sprechen in den Dreiklangdimensionen Grundfrequenz, Dauer und Intensität gibt. Es wird ein Abtast-Modell vorgestellt, das auf den Differenzen zwischen den wahrgenommenen Niveaus der drei Dimensionen aufbaut. Betrachtungen der in einem alphabetischen Ansatz enthaltenen Informationen werden besprochen.

## The Authors

W. C. Watt is professor of cognitive sciences at the University of California, Irvine (Irvine, CA 92664), where he teaches iconics and related aspects of visual culture, including architecture. He has taught computational linguistics at Carnegie-Mellon University in Pittsburgh, and for three years was in the Applied Mathematics Division at the National Bureau of Standards, where he pursued research in computational linguistics and computational iconics. Dr. Watt has published a number of papers on these topics, including two on the iconic of Nevada cattlebrands, as well as several papers in linguistic theory. He is currently preparing Parts II and III of this series of papers, and investigating some architectural ideas current between 1850 and 1900.

Marcia Ascher, professor of mathematics at Ithaca College (Ithaca, NY 14850), is a mathematician whose special fields of interest are numerical analysis and the relationships between mathematics and culture. The latter includes the kind of work reported here on Inca Civilization as well as topics such as computer impact on American society. Her most recent papers include "Cycling in the Newton-Raphson Algorithm" and "Computers in Science Fiction (II)."

Robert Ascher, professor of anthropology and archaeology at Cornell University (Ithaca, NY 14850), has excavated in Turkey, Mexico, and the United States; he did above-the-ground archaeology in South America and Europe. In recent years, his interest in the near contemporary culture of the U.S.A. has been expressed in publications such as "How to Build a Time Capsule" and "Excavations of a Slave Cabin, Georgia, U.S.A." Currently, he is interested in visual anthropology; in particular, he builds constructions and sculptures to express anthropological ideas.

The interest of Ernest Robson (Parker Ford, PA 19457) in poetry and language developed while he was a student of Robert Frost at Amherst College in 1923-24. He has worked as a detergent chemist for government and industry. Since 1955 he has been a researcher and writer of experimental sound poetry and an active amateur astronomer. He is chairman of the Bicentennial Convention for the Astronomical League, the national organization of 7,500 amateur astronomers. An interest in relating the sciences and the arts led to the development of prosodynamic print. His books include *The Orchestra of the Language* (1959), *Transwhichics* (1970), and *I Only Work Here* (1975).

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