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The First Alphabetical Treatises in the Renaissance

Millard Meiss

Treatises on the design of the alphabet were an innovation of the early Renaissance and reflect that period's conception of a world ordered by numerical proportion and geometric shape. The interrelationship of the various men and their theories is discussed and illustrated. Although Felice Feliciano inaugurated these alphabetical treatises, Andrea Mantegna is shown to have had an important place (if not key role) in the revival of the roman letter.

A new form of didactic and theoretical writing appeared in the early Renaissance: treatises on the design of the alphabet, which is to say, of course, the roman alphabet. The first of these texts known to us was written by none other than Felice Feliciano, a friend of the painter Andrea Mantegna who recorded the chief events in a famous archaeological trip they made together to the Lago di Garda. Feliciano's treatise on the alphabet was followed by similar "*trattati delle lettere antiche*," one by Damiano Moille, printed at Parma ca.1480, another by Luca Pacioli, printed in Venice in 1509, and still another by Sigismondo de' Fanti, printed in Venice in 1514.[1] This species of literature was then adopted north of the Alps, appearing first as a section of Dürer's *Underweysung der Messung*, printed in 1525.

Treatises of this sort seem to be entirely novel; they were, at least, written without awareness of precedents in antiquity. They bear witness to the seriousness of the concern of Quattrocento artists and humanists with the creation of a new script, based on Roman example. They also testify to the desire of these innovators to describe, record, and communicate their intellectual and artistic conquests, contributing thereby to the advancement of contemporary culture, of whose progress they held such an unshakable conviction. The treatises reflect also the desire of these men to get at fundamental laws, even those underlying the shapes of letters. In fact the primary motive of Feliciano, Moille, and Pacioli was to demonstrate the principles of proportionality in the *lettera antica formata*, as the formal script in the new style was called. Sigismondo de' Fanti says at the beginning of his discussion of the majuscules (Book IV) that he wishes to impart the principles of the letter "cum doctrina erecta," and this *doctrina* is based on the premise, ultimately Greco-Roman itself, that "nature has ordered the things of this earthly microcosm according to their true and proper proportions." Feliciano introduces his discussion of the first letter of the alphabet as follows (Fig. 7):

"According to ancient practice the letter is shaped from the circle and the square, the sum of whose forms rises to 52, from which is drawn the perfect number, which is 10. And thus the width (of the stroke) of your letter should be one-tenth of its height. In this way the letter has as much of the circle as of the square. . . ."[2]

Thus in the very first account of the "exquisite litere latine antiquarie," as Francesco Colonna describes them in the *Hypnerotomachia*, the premises conform to the mathematical mystique of the early Renaissance. It was not only the world and man and architecture and music that possessed beauty as the consequence of an inherent numerical proportionality, but the letters of the alphabet as well! In the passage quoted above, Feliciano probably had Vitruvius in mind. It was probably from Vitruvius that he derived the idea of the perfection of the number 10, which the Roman writer in turn admits having taken from the "ancients," particularly Plato and the Pythagoreans.[3] These older writers, Vitruvius says, considered 10 perfect because of its relation to members of the body—fingers and toes—and also because it is equal to the sum of the *monades* ($10=1+2+3+4$). The human body, Vitruvius adds, manifests a canon of proportion that is based on the ratio $1=10$. The figure may be divided longitudinally into 10 units, each of which is equal to the face from the chin to the top of the forehead.

It was, moreover, not only the idea of the perfection of 10 that Feliciano took from Vitruvius. In his treatise he proceeded to apply to capital letters the perfect forms of the square and the circle that, when applied by Vitruvius to man, had stirred the imagination of Ghiberti, Leonardo, and the entire Renaissance. In short, to the Vitruvian *homo ad quadratum et ad circulum* Feliciano and his successors

Figure 1. Mantegna, *Lettering on gesso*, Altarpiece, Verona, S. Zeno.

Figure 2. Mantegna, 1456–7, Inscription on tablet, Padua, Eremitani, *Martyrdom of St. Christopher* (detail).

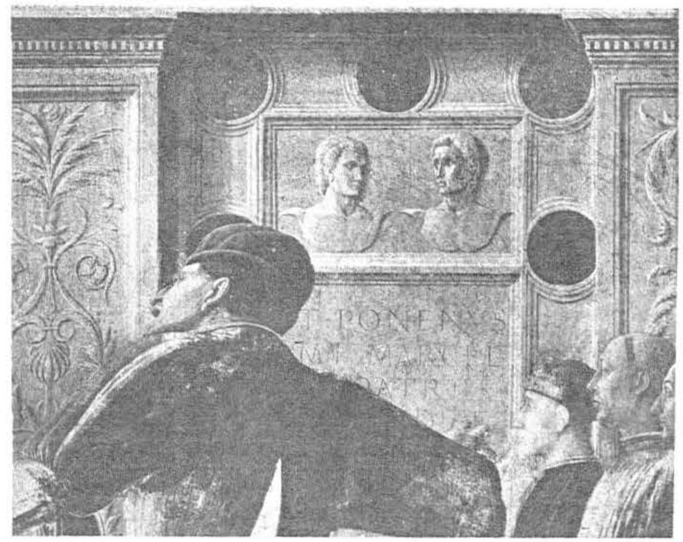


Figure 3. Mantegna, *Initial P*, Albi, Bibliothèque Rochegude MS 4, f. 117.

Figure 4. Mantegna, *Initial A*, Albi, Bibliothèque Rochegude MS 4, f. 183v.

Figure 5. Mantegna, *Initial E*, Albi, Bibliothèque Rochegude MS 4, f. 230v.

Figure 6. Mantegna, *Initial H*, Albi, Bibliothèque Rochegude MS 4, f. 273.

add the *littera ad quadratum et ad circulum*. The letters of the alphabet, like the human body, manifest a geometric as well as a numerical canon.

Feliciano's ideas and procedures were adopted and given a more philosophical explanation by Luca Pacioli, who wrote a half century later. In the *Divina proportione*, to which his little treatise on letters is appended, he says that "the ancients, after having considered the right arrangement of the human body, proportioned all their work, particularly the temples, in accordance with it. For in the human body they found the two main figures without which it is impossible to achieve anything, namely the perfect circle . . . and the square." Pacioli adds a metaphysical interpretation of these figures and of the shape of the body: ". . . from the human body derive all measures and their denominations and in it is to be found all and every ratio and proportion by which God reveals the innermost secrets of nature."[4] These secrets are evidently inherent also in the perfect capital letter (Fig. 24).

The man who, as far as we now know, inaugurated the Renaissance tradition of alphabetical treatises, Felice Feliciano, was an almost exact contemporary of Andrea Mantegna.[5] Famous as one of the first collectors of ancient inscriptions, and nicknamed "l'antiquario," he was also something of a poet, a printer, and towards the end of his life, an alchemist. He transcribed a biography of his Quattrocento predecessor in epigraphy, Ciriaco d'Ancona. Among painters he knew Marco Zoppo and Giovanni Bellini as well as Mantegna, and on one occasion he addressed to the latter a sonnet pleading for assistance in his poverty. We know that in 1464 he joined the excursion to the Lago di Garda; in 1474–5 he was in Venice and Ferrara; in 1476 he printed a Petrarch, *De viris illustribus*, at Pojano; and he died around 1480. In 1463 he dedicated a collection of inscriptions to Mantegna, "amicus incomparabilis," speaking warmly of their common passion for ancient culture, and praising the painter's learning and archaeological experience.[6] The most important of his epigraphical manuscripts, preserved in the Vatican Library, contains also the treatise on the alphabet (Figs. 7–12).[7]

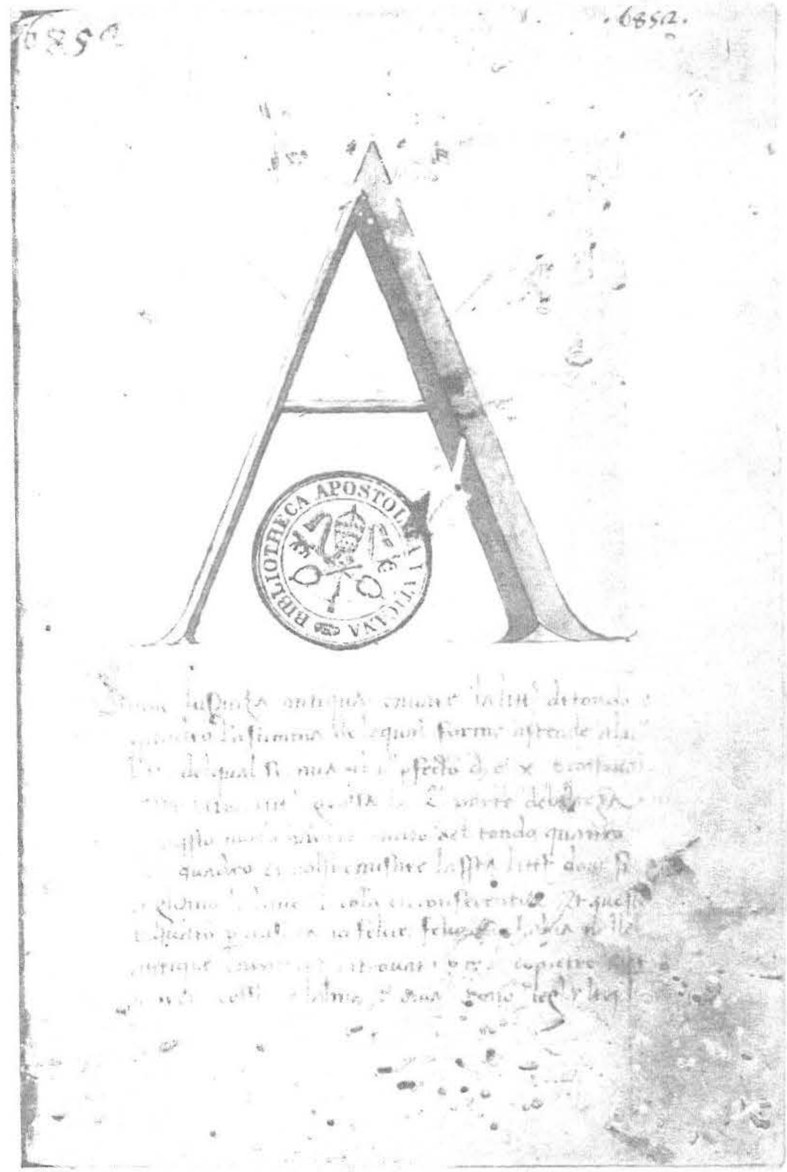


Figure 7. F. Feliciano, *A*, Rome, Biblioteca Vaticana, lat. 6852, f. 1.

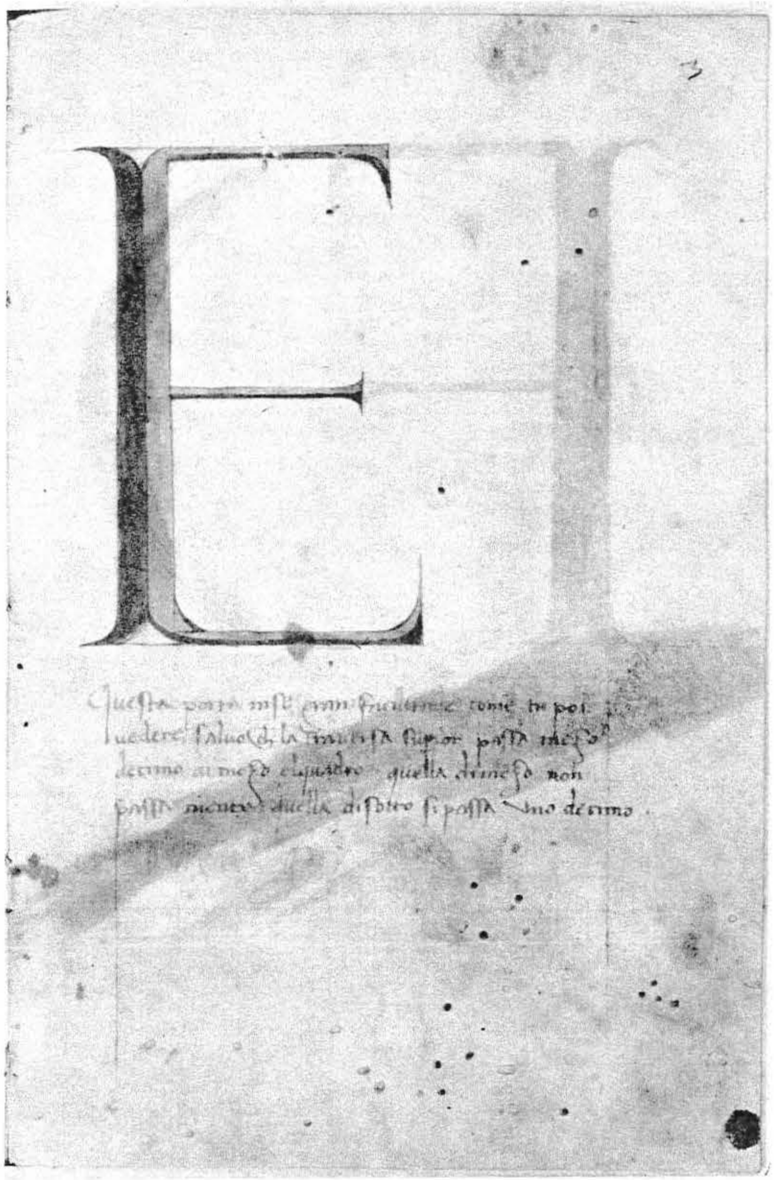


Figure 8. F. Feliciano, *E*, Rome, Biblioteca Vaticana, lat. 6852, f. 3.

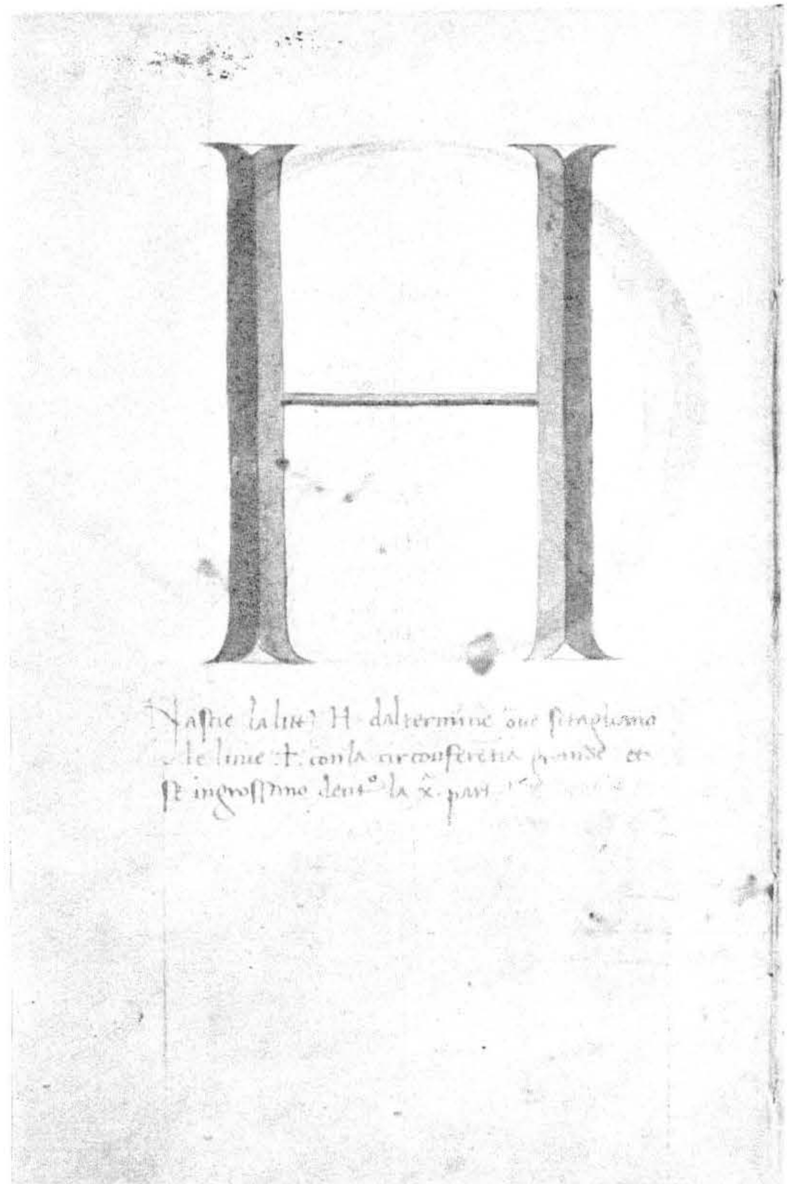


Figure 9. F. Feliciano, *H*, Rome, Biblioteca Vaticana, lat. 6852, f. 4v.

Figure 10. F. Feliciano, *M*, Rome, Biblioteca Vaticana, lat. 6852, f. 6v.

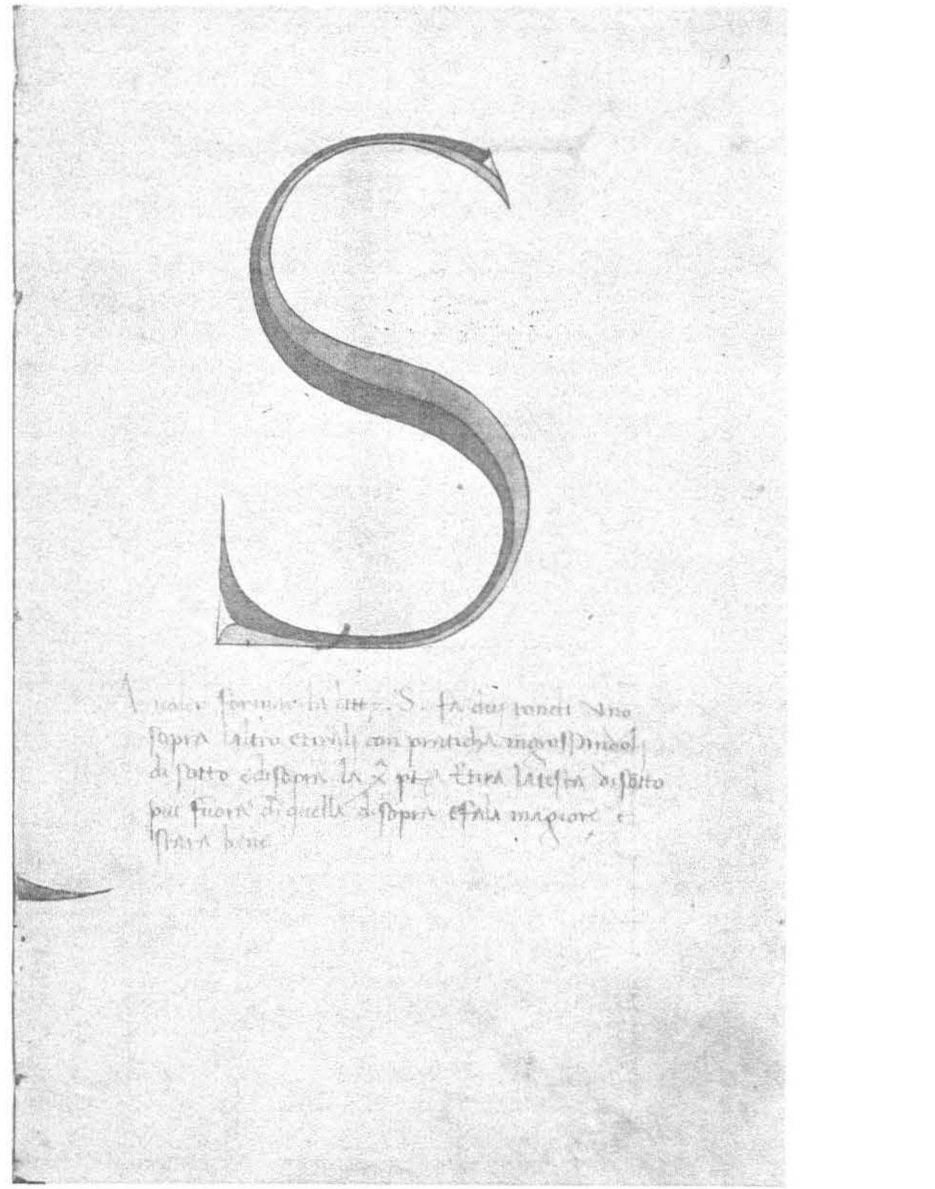


Figure 11. F. Feliciano, *S*, Rome, Biblioteca Vaticana, lat. 6852, f. 10.

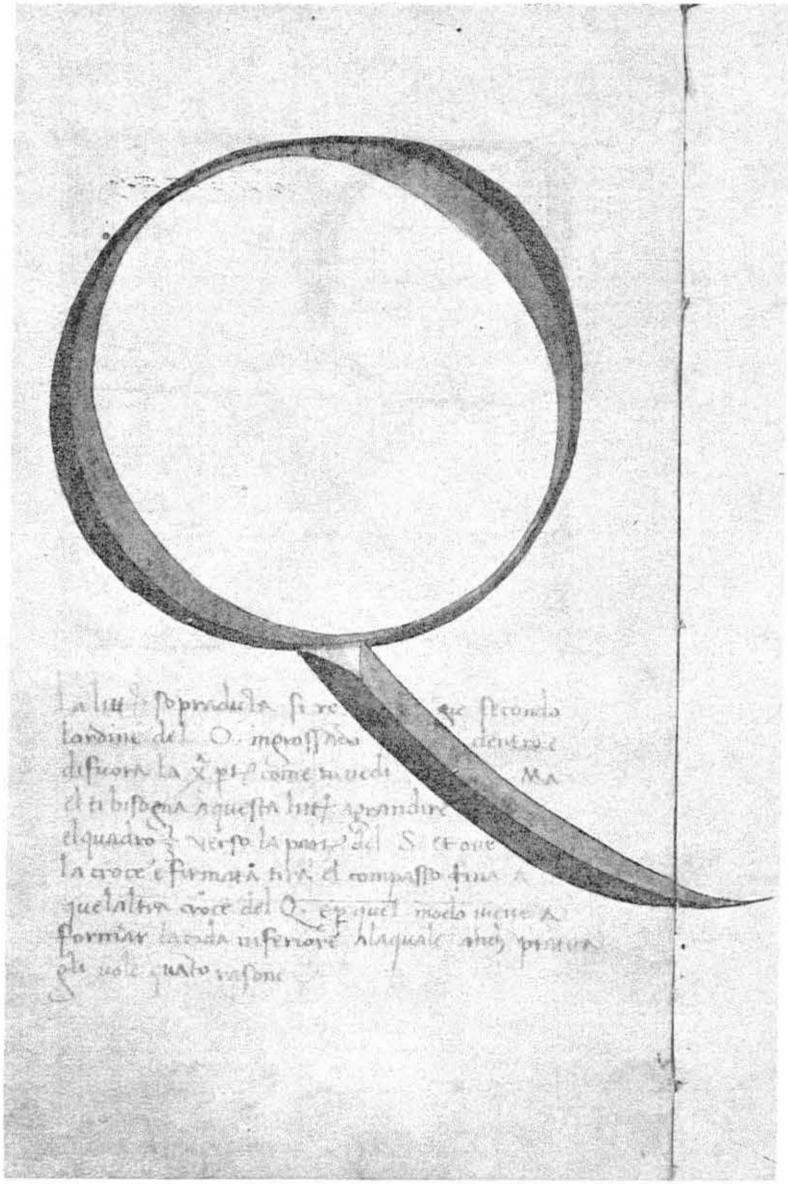


Figure 12. F. Feliciano, *Q*, Rome, Biblioteca Vaticana, lat. 6852, f. 9v.

Like the capital A discussed above, all of Feliciano's letters exhibit his conception of the perfect Vitruvian ratio, 1 = 10. After giving an account of D, Feliciano adds: "Nota non te domenticar far tutte le littere grosse la parte X^{a}." Although Feliciano's concern with proportion and geometry is essentially theoretical, it is occasionally bound up with practical and didactic purposes. Of the R he says: "La piu difficil parte di questa littera (e) la coda perche non vi si trova alchun tracto di compasso perfecto . . . e fassi la coda . . . per praticha piu che per rasone. . . ."[8] R, not reducible to proper geometry, is a sort of second-class letter.

Close study of Feliciano's manuscript proves that he not only advocated geometric construction of the majuscule but applied his principles, in the case of many letters at least. Faint traces of circles, squares, and diagonals, as well as the central prick of the foot of the compass, may be seen on many folios. These geometric forms were drawn in the brownish ink used afterwards to outline the letters, and they were erased after the shapes of the letters had been determined. Geometry had, however, only a proximate meaning. Feliciano, for instance, preferred a narrow H and he produced it, even though it does not come near to filling the square with which he began.

The capitals in Feliciano's alphabet are prismatic, and in this respect they resemble the much more beautiful capitals in the initials of a manuscript of Strabo, *De Situ Orbis*, which can be dated 1459 (Figs. 3–6). These splendid letters approximate so closely the capitals in contemporary inscriptions by Andrea Mantegna (Figs. 1, 2) that they seem to me to have been designed by him and painted in his workshop.[9] If this is true, how are we to understand the relationship between Feliciano and Mantegna? Was the prismatic letter introduced earlier, in examples unknown to us, and then greatly refined by Mantegna? The known facts of its history seem to disprove this. Could Feliciano, professional antiquary, have been its creator? The problem is somewhat complicated by the fact that Pratilli has recently shown that the Vatican manuscript, contrary to general belief, is not dated, though some facts do point to ca. 1463, the year when it is commonly believed to have been finished.[10] We are therefore thrown back on internal evidence, and fortunately this seems clear and decisive.

Feliciano, first of all, was not an artist nor even a first-rate calligrapher. A Latin miscellany preserved in the Museo Correr at Venice provides abundant proof of that. Dated 1460, it contains the statement "scripto e miniato per mano di me felice feliciano da Verona. . . ."[11] We can be certain then—or, intellectuals being what they are, reasonably certain—that the initials in this manuscript were painted by Feliciano himself (Fig. 13). They are altogether conventional.[12] The letters themselves are not only without special distinction but are strikingly similar to those in the Vatican manuscript, so that we can assume that the latter also are specimens of Feliciano's limited craft. They are scarcely comparable to those in the *Strabo*. The transversal in Feliciano's H, for instance, is painfully thin, especially for a statuesque letter. The letters generally lack the entasis and other refinements of the *Strabo* letters, and while they are constructed in light and dark, these value changes are unpredictable and unsystematic. In the *Strabo* the light strikes the initials consistently from the upper left. Feliciano's R is lighted from the right, while the H (Fig. 9) is lighted from within and the A (Fig. 7) from both sides. Surely Feliciano was applying, with limited comprehension, a principle initiated by the friend and colleague to whom he dedicated his treatise.

Given the friendship of Feliciano and Mantegna, as well as their known collaboration in the study of antiquity, we might suppose that the proportions of their letters would be the same. Such, however, is not the case. The *Strabo* capitals were perhaps laid out on a square and a circle (Figs. 16, 17), but their ratios do not conform to the prescriptions of Feliciano. When the latter tells us, in the passage quoted above, that the "width" of the letter A is $\frac{1}{10}$ of its height, he undoubtedly refers to the ratio of width to height in the right shank (Fig. 7). The corresponding ratio in the *Strabo* is about 1 to 12 (Fig. 16). If we turn to other letters, H for example, we discover similar differences. Feliciano again stipulates a ratio of 1 to 10 for both the uprights (Fig. 9), whereas Mantegna, with equal consistency, again employed 1 to 12 for the more important right shank, while reducing the left—for the sake of a more active pattern—to about 1 to 16 (Fig. 17). Feliciano prescribes for E an upper transversal that passes the axis of the square by a half of a tenth, while the lower transversal passes it by one-tenth. In the *Strabo* the variation in the lengths (as well as the thicknesses) of the three transversals is greater. The lower

Figure 13. F. Feliciano, *Q*, Venice, Museo Correr MS 314, VI, 351, f. 12.

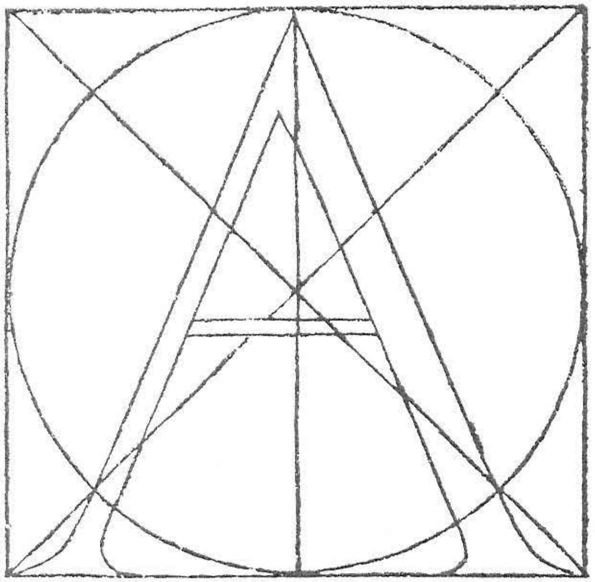
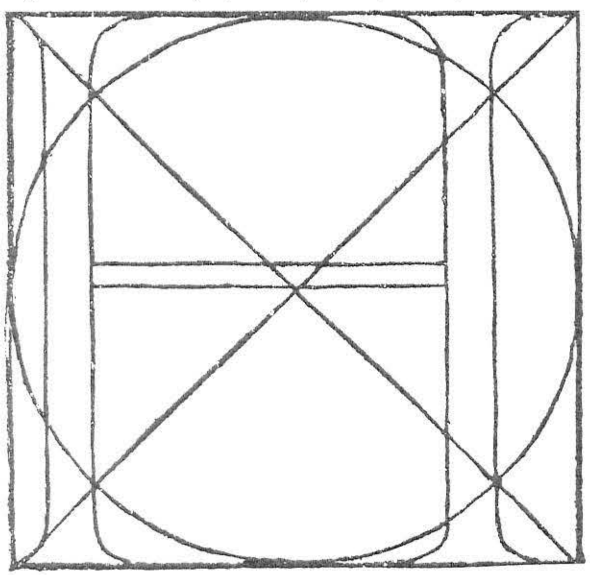


Figure 14. D. Moille, *A*, from *Alphabetum*, Parma, ca.1480.

Figure 15. D. Moille, *H*, from *Alphabetum*, Parma, ca.1480.



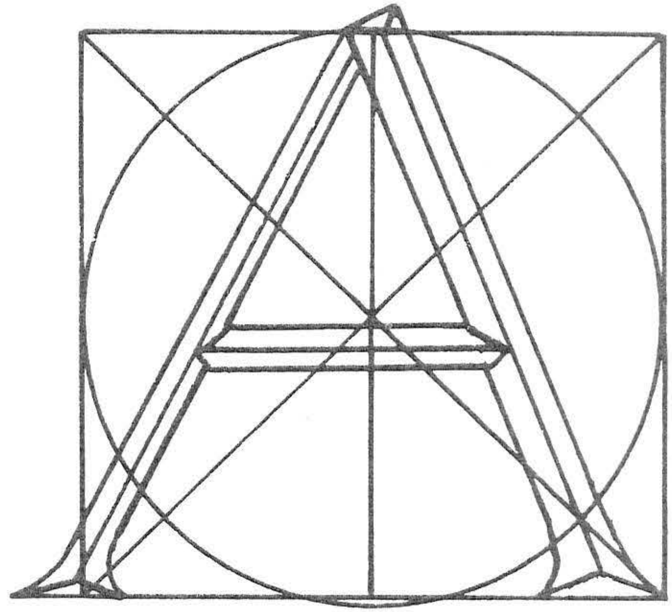
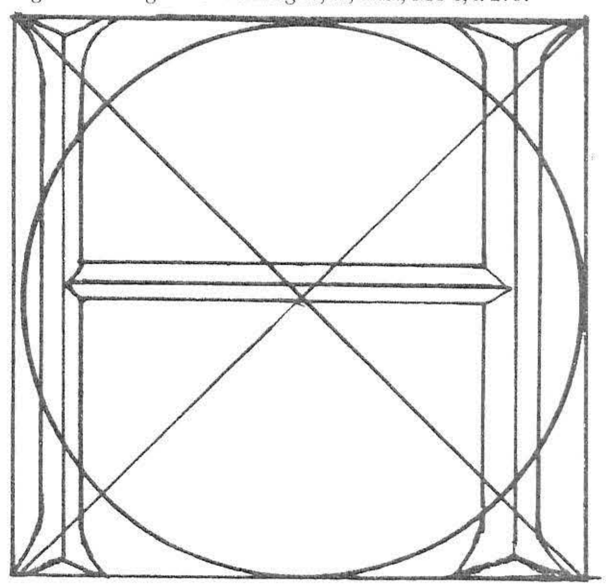


Figure 16. Diagram of Mantegna, *A*, Albi, MS 4, f. 183v.

Figure 17. Diagram of Mantegna, *H*, Albi, MS 4, f. 273.



COMPARATIVE TABLE OF PROPORTIONS

	STRABO (MANTEGNA)	FELICIANO	MOILLE	PACIOLI
A				
width r. shank	ca. $\frac{1}{12}$ height	$\frac{1}{10}$ height	$\frac{1}{12}$ height	$\frac{1}{9}$ height
width l. shank	ca. $\frac{2}{5}$ width r.	ca. $\frac{1}{3}$ r.	$\frac{1}{2}$ width r.	$\frac{1}{2}$ width r.
width transversal	ca. $\frac{3}{5}$ width r.	ca. $\frac{1}{5}$ r.	$\frac{1}{3}$ width r.	$\frac{1}{3}$ width r.
location of transversal	below center	just below center	one thickness of r. leg below center	below crossing of diagonals
E				
width upright	ca. $\frac{1}{12}$ height	ca. $\frac{1}{9}$ height	$\frac{1}{12}$ height	$\frac{1}{9}$ height
width upper transversal	ca. $\frac{1}{3}$ width upright	ca. $\frac{2}{11}$ width upright	$\frac{1}{2}$ width upright	$\frac{1}{2}$ width upright
width middle transversal	ca. $\frac{2}{3}$ width upright	ca. $\frac{2}{11}$ width upright	$\frac{1}{2}$ width upright	$\frac{1}{3}$ width upright
width lower transversal	ca. $\frac{1}{2}$ width upright	ca. $\frac{2}{9}$ width upright	$\frac{1}{2}$ width upright	$\frac{1}{2}$ width upright
H				
width r. shank	ca. $\frac{1}{12}$ height	$\frac{1}{10}$ height	$\frac{1}{12}$ height	$\frac{1}{9}$ height
width l. shank	ca. $\frac{1}{16}$ height	$\frac{1}{10}$ height	$\frac{1}{12}$ height	$\frac{1}{9}$ height
width transversal	same as l. shank	ca. $\frac{2}{9}$ width upright	$\frac{1}{3}$ width upright	$\frac{1}{3}$ width upright
location of transversal	just above middle	just above middle	just above middle	passes through middle

Ratios derived from measurement of the initials are only approximate.

transversal is actually shorter than the upper, but it has a larger serif. The ratio of width to height in the upright is again about 1 to 12.

In his choice of a ratio of 1 to 12 Mantegna, like Feliciano, may have intended to conform to ancient authority, particularly Vitruvius. Actually this writer, in the same passage on proportion to which we have referred above, says that while many of the "ancients" held 10 to be the perfect number, others preferred 6. Twelve was an essential part of the numerical pattern that is inherent in 6, and it was called *diplasios*.

Measurement of initials like those in the *Strabo*, whose parts are merely a fraction of a centimeter wide, is of course only approximate, and our belief that Mantegna had in mind the ratio 1 = 12 therefore receives welcome support from the theory of Damiano Moille. This stationer, miniaturist, and calligrapher of Parma produced in that city around 1480 the first printed treatise on the design of the *littera antiqua* (Figs. 14, 15).[13] The little book, printed on only one side of the sheet and unbound—probably because it was intended only for craftsmen—combines a short description of each letter with a diagram that shows it inscribed within a circle and a square. The author prescribes for the ratio of the width of an upright to its height the same ratio that we supposed to be inherent in the *Strabo*. "The I," Moille says, "should be of a width that is the twelfth part of the height of the square, like all the other letters." In describing the A, Moille says that the right shank is $\frac{1}{12}$ of its height, and then stipulates for the other shanks some of the ratios that, according to the ancients, contribute to the perfection of 6 ($\frac{1}{2}=3$, and $\frac{1}{3}=2$). The width of the left shank is $\frac{1}{2}$, and the transversal is $\frac{1}{3}$, of the right shank. Such variations, lacking in Feliciano's A (Fig. 7), may be found in the *Strabo* (Fig. 16). Here, however, the relation of the transversal to the left shank is reversed, the transversal in the *Strabo* being larger than the left shank in the ratio of ca. 3 to 2.[14]

The comparative massiveness of the transversal of the A, together with its low position and the wide spread of the shanks, increases the weight and the monumental effect of the letter. These qualities characterize all the letters in the *Strabo*. The H, for instance, whose uniquely varied verticals we have already mentioned, is equally unique for its overall width (Fig. 17). It approaches closely a square, more closely at any rate than Moille's H, which leaves an unfilled

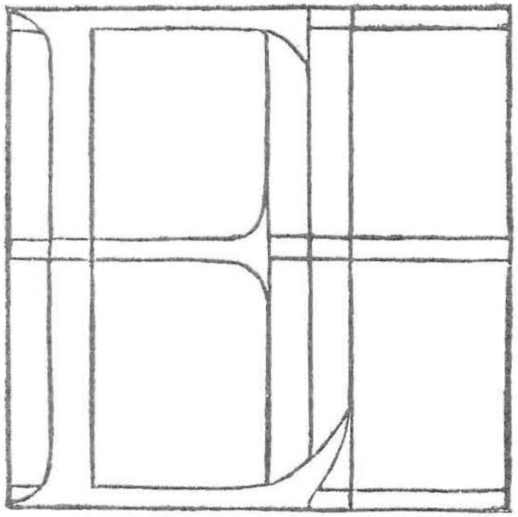


Figure 18. D. Moille, *E*, from *Alphabetum*, Parma, ca.1480.

space at the right (Fig. 15). In Moille's constructions, as well as in those of Pacioli and other later writers, the letters frequently fail to fill the square or project a little beyond it. The ideal shape is only approximated. Geometry provides guidance without exerting strict control.

The relations of Feliciano and Moille with the *Strabo*, and with one another, are evidently quite complex. Only Feliciano adopts the letter in relief, but Moille's proportions are closer to Mantegna's. Luca Pacioli's connections with his predecessors are no less complex (Figs. 20, 21).[15] It has been argued that he knew both Feliciano and Moille, even though he didn't follow either very closely. And when one considers such aspects of the letters as the serifs, it is apparent that though Moille, like the Romans themselves, omits top serifs on M, Pacioli as well as Feliciano employs them.[16] At the same time Pacioli's letters, shaped in 1509 in the period of the High Renaissance, are squarer and bulkier than those of his predecessors. This change is reflected in his basic proportion of the width of the stroke to its height, which is no longer 1=12, but 1=9. The ratio of the smaller stroke to the larger—the transversal of H, for instance, to the uprights (Fig. 21), or the transversal of A to the right shank (Fig.

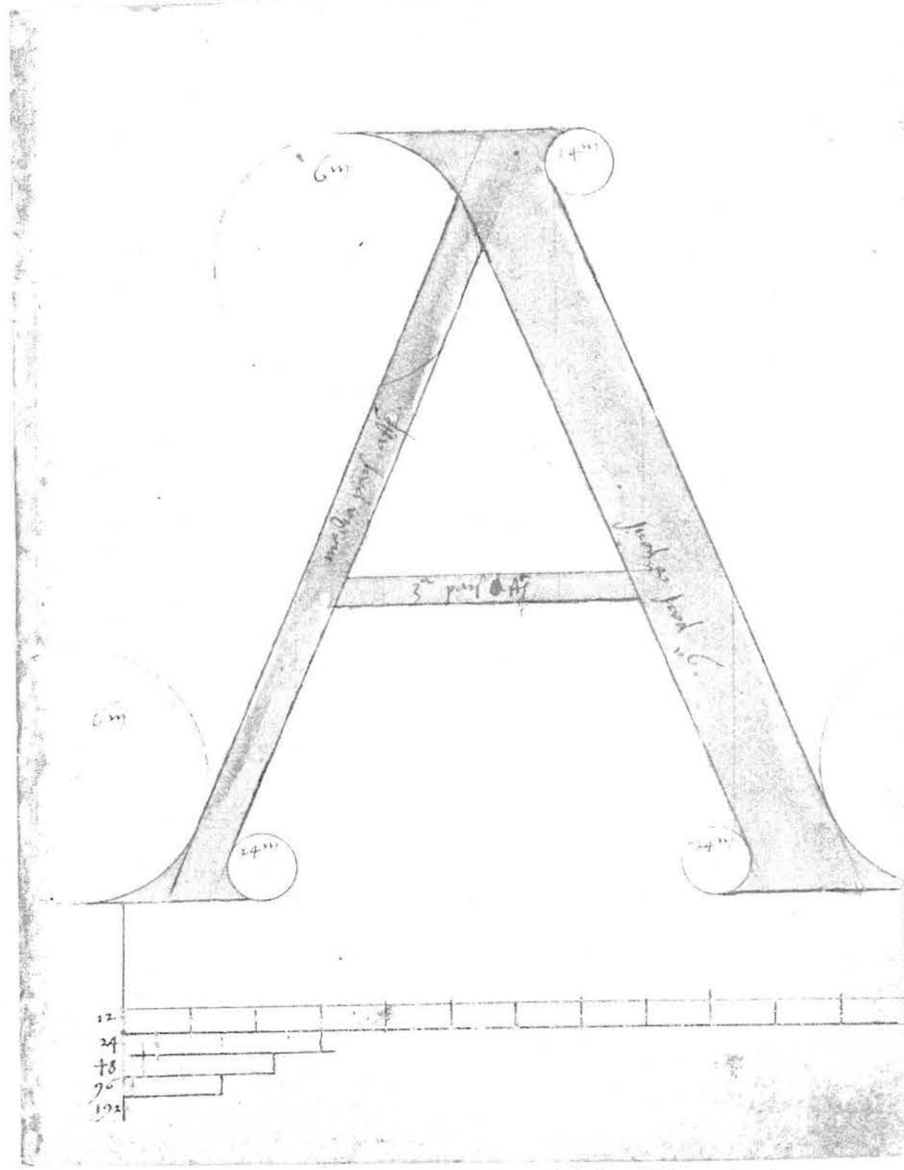


Figure 19. Italian late XV century, *A* from an alphabet, Chicago, Newberry Library.

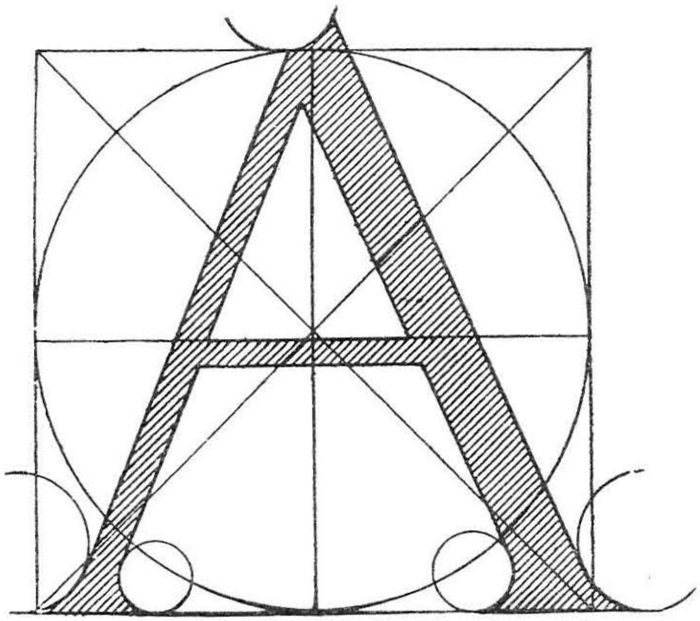
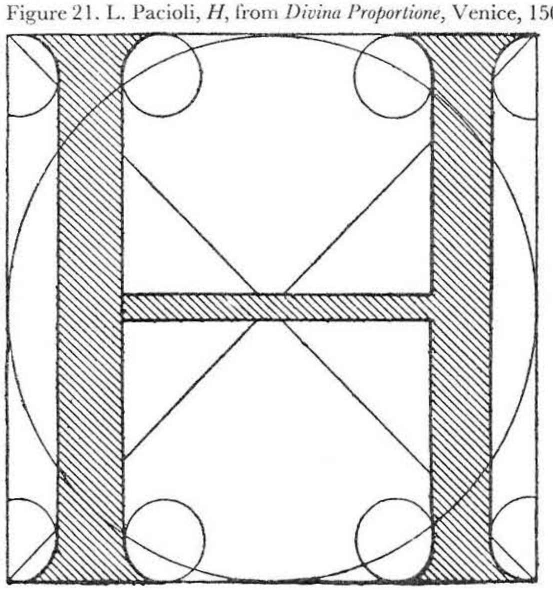


Figure 20. L. Pacioli, *A*, from *Divina Proportione*, Venice, 1509.

Figure 21. L. Pacioli, *H*, from *Divina Proportione*, Venice, 1509.



20)—is moreover often 1=3. In all of this (1-3-9) we recognize not only a predilection for a certain shape but for a certain abstract proportion, namely the Platonic, as set forth in the *Timaeus*.

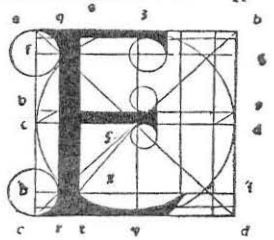
Pacioli is the last of the major early Italian theorists of the design of the alphabet. Sigismondo de' Fanti's book, published in Venice five years after Pacioli's, is notable chiefly as a full-fledged manual, giving precise and detailed instructions for the construction of the letters, which are illustrated by complex diagrams (Fig. 22).[17] It is a sign of the times that Fanti should discuss first not Roman capitals but Gothic minuscules. As we have observed elsewhere,[18] after the first wave of enthusiasm for the *littera antiqua* Gothic letters returned to favor, especially for religious texts.

But an account, however brief, of the first half century of the theory of the design of the alphabet cannot end with Pacioli, and much less with Fanti. For a highly significant contribution was made at this time, first apparently by the originator—whoever he was—of the ideas contained in a manuscript that belonged in the early sixteenth century to the Nürnberg physician and scholar, Hartmann Schedel. This manuscript, of which only the briefest notices have been published,[19] proposes three possible ratios for the letters: 1=12, 1=10, 1=9, though 1=10 is favored. A similar concept of alternatives emerges in the thought of Albrecht Dürer, perhaps inspired by this anonymous text. Dürer in any event had been twice to Venice, and he was no doubt familiar with at least those alphabetical treatises that had been published, two of which had appeared in that city itself. Just as in his speculation about the human figure Dürer had come to recognize more than one beautiful form and one canon of proportion,[20] so in his account of roman capitals in the *Underweysung der Messung* he presented more than one perfect example of each letter. He offered for each letter the ratio 1=9 as well as 1=10, and two or more shapes, recommending to the reader the use of the one "weliche dir am basten gefelt." Thus Dürer and his anonymous forerunner undermined the central concept of the earlier theorists—that of a single perfect form. Without abandoning geometry and numerical law they opened the door to multiformity and to individual taste.

But the idea of a perfect letter, possessing a fixed proportion, continued to haunt the sixteenth and seventeenth centuries. Indeed in

QVARTVS.

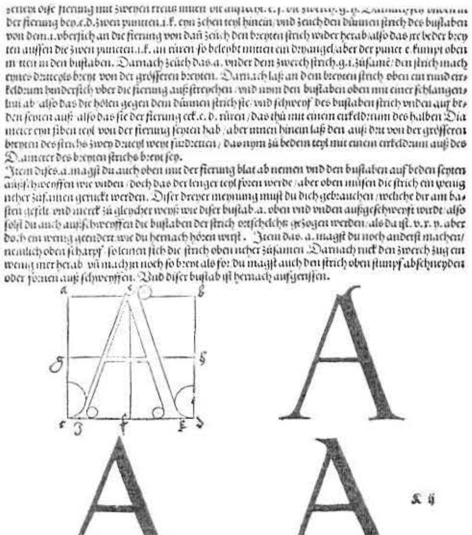
LA littera.E.antiqua certamente cauarse da le medesime circũstantiæ & modi de la præcedẽte nõ negamo. Quãdo adũque lasta naturale de q̃sta littera sera cũ le medesime normæ,ptracta.Faciasse sopra il cẽtro.E. cõmuno la portiõe del circulo.x.y.secũdo la q̃tita de.e.x.tãgendo lo diametro a.d.in.y.dal q̃le puncto sia la linea.y.z.ppendiculariter extẽduta sopra il diametro.a.d.per la.xi. de Euclide:& de ditta lr̃a la gamba iferiore hauerai fabricato:e se la supiore gãba uorai generare. Alhora dal pũcto.z.per la.xi.del Megarẽse sia la linea.z.&. ppendiculariter



sopra lo lato.c.d.ptracti:secãdo.f.g.in.ↄ.Et qñ il circulo paruo sopra il centro.ꝶ.sera descripto secũdo la q̃tita de.ꝶ.ↄ.la quale e posta essere æquale a li tri quarti de la largheza de la pẽna cioe de. f.a. Et q̃sto fatto se la media asta.A.C.B.D.cõtingẽte al cẽtro.e.cõmuno sera lineata il cui termio sia la linea.E.F.distãte da la linea.u.z.p tri q̃rti de testa.Hauerai alhora la mediale gãba de dita lr̃a cũ doctrina erecta.Et maxie qñ p gr̃a de q̃lla li serano li dui paruissimi circuli secũdo la q̃tita de media testa descripti.Se da poi li dui parui circu

Figure 22. S. de' Fanti, *E*, from *Theorica et Practica de modo scribendi*, Venice, 1514.

Figure 23. A. Dürer, *A*, from *Underweysung der Messung*, Nürnberg, 1525.



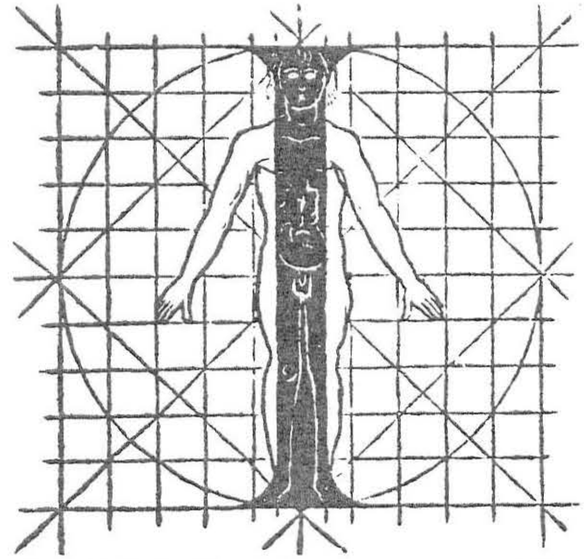
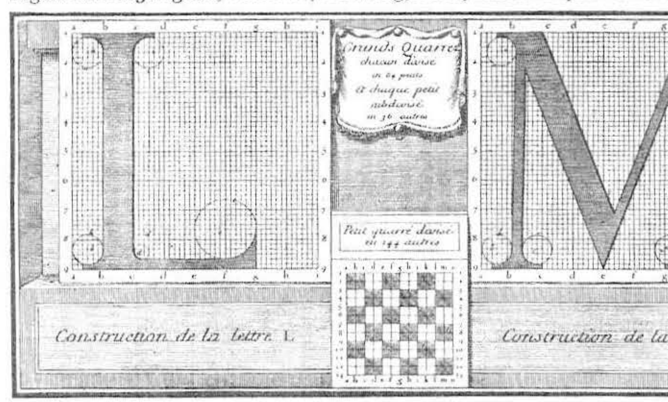


Figure 24. Geofroy Tory, *I*, from *Champ Fleury*, Paris, 1529.

Figure 25. N. Jaugeon, *L* and *M*, Drawing, Paris, Bibliothèque Nationale.



France, where Italian criticism and theory were rigorously systematized, the mathematical determination of letters was raised to an astonishing level of precision. In 1692 the *Académie des Sciences*, composing a set of models of capitals for the engraver of the *Imprimerie Royale*, laid them out on a field subdivided into 2304 squares (Fig. 25). The story is not complete however without adding that the engraver, confronted with these laboriously contrived geometric patterns, absolutely refused to adhere to them, insisting that the eye was the sovereign creator and judge of form.[21] Mantegna and his contemporaries would probably not deny this, but they would not, at the same time, sense an inherent conflict. Even while invoking geometry as a guide to form they assumed its limits, and they knew intuitively how to make something living and personal of it.

This article is adapted from chapter IV in Millard Meiss, *Andrea Mantegna as Illuminator, an Episode in Renaissance Art, Humanism, and Diplomacy*. New York: Columbia University Press.

1. There is also a manuscript on letter design now in the Newberry Library, Chicago, formerly in the Ricketts Collection (Fig. 19). Measurements and brief instructions are written on or around the letters (Cf. F. W. Goudy, "The Roman Alphabet," in *Ars Typographica*, II, 1926, pp. 202–5, with an unfounded ascription to Leonardo—see below, note 15). I have been unable to find reproductions of another alphabet in the Bayerische Staatsbibliothek, Munich, Clm 451. See below, note 19.

2. "Suole lusanza antiqua cauare la littera di tondo e quadro, la summa de le qual forme ascende al numero LII, del qual si caua il numero perfecto che e. X. e cossi uol esser la tua littera grossa la X^a^. parte delalteza et per questo modo hauere tanto del tondo quanto del quadro . . ."

3. Vitruvius, Book III, chapter 1.

4. *Divina proportione*, ed. C. Winterberg, Vienna, 1889, pp. 129, 131. The two passages are quoted above in the English translation given by R. Wittkower, *Architectural Principles in the Age of Humanism*, London, 1949, p. 14.

5. He was born in 1431. The published accounts of the life and works of Feliciano evidently abound in error. A recent study by L. Pratilli, "Felice Feliciano alla luce dei suoi codici," in *Atti del Reale Istituto Veneto di Scienze, Lettere, ed Arti*, XCIX, 1939–40, pp. 33–105, makes real progress, but much remains to be done. See also G. Tiraboschi, *Storia della Letteratura Italiana*, ed. Milan, 1824, VI, 1, p. 304, and S. Maffei, *Verona Illustrata*, Milan, 1825, III, p. 191 ff.

6. Ms. 269, Biblioteca Capitolare, Verona. The dedicatory preface is printed in Pratilli, *op. cit.*, p. 49.

7. Ms. lat. 6852. The text on the alphabet was printed by R. Schöne, "Felicis Feliciani Veronensis Opusculum ineditum," in *Ephemeris Epigraphica*, Rome, 1872, p. 255 ff. See also J. Poppelreuter, "Zu Felice Felicianos römischen Schriftformen," in *Repertorium für Kunstwissenschaft*, XXVII, 1904, pp. 57–60 (with the incorrect statement that the Vatican manuscript was finished in 1481), and R. Bertieri, "Gli Studi Italiani sull'Alfabeto nel Rinascimento," in *Gutenberg-Jahrbuch*, 1929, p. 269 ff. The letters E, M, S have not hitherto been reproduced.

W. R. Koehler has kindly informed me of a sort of Carolingian prelude to this Quattrocento concern with the measurement of roman script, described in a letter dated 836 of Lupus of Ferrières to Eginhard. "Praeterea scriptor regius Bertcandus dicitur antiquarum litterarum, dumtaxat (i.e. videlicet) earum quae maximae sunt, et unciales a quibusdam vocari existimantur, habere mensuram descriptam." (Cf. *Lettres de Servat Loup, Abbé de Ferrières*, ed. Desdevises, Paris, 1888, pp. 60–61.)

8. Drawings of all these letters were published by Schöne, *op. cit.* Pratilli, *op. cit.*, reproduces photographs of several.

9. The relationship of the *Strabo* capitals to Mantegna, and Mantegna's role in the revival of the Roman imperial majuscule—a major one, in the writer's opinion—are discussed in Meiss, *op. cit.*, pp. 52–67, and idem, "Toward a More Comprehensive Renaissance Paleography," *Art Bulletin*, XLII, 1960, pp. 97–112.

10. The date 1481 on f. 17, taken by some students to be determining, is actually, according to Pratilli (*op. cit.*, p. 58) an addition.

11. Museo Correr, ms. 314. VI, 351, f. 5. Cf. Pratilli, *op. cit.*, p. 96.

12. A similar kind of interlace appears in the friezes of the Petrarch printed by Feliciano (cf. Pratilli, *op. cit.*, fig. 7).

13. Cf. the facsimile published by S. Morison, *A Newly Discovered Treatise on Classic Letter Design*, Paris, 1927. Damiano was born shortly after 1439 and died probably in 1500. Cf. also *Tesori delle Biblioteche d'Italia, Emilia e Romagna*, Milan, 1932, p. 542 and figs. 305–6.

14. The relationship is peculiar to the Strabo, and differentiates it from all the treatises, including Pacioli's.

15. The opinion, shared by Morison (*op. cit.*, p. 20), that Pacioli wrote his account of the alphabet in 1483, has been refuted by R. Bertieri, *op. cit.* Bertieri shows that this treatise was written expressly for the volume of the *Divina Proportione* published in 1509. Bertieri argues also that there is no substance in the old view that Pacioli's letters were drawn by Leonardo, and he suggests instead (with little evidence) Piero della Francesca. Bertieri also points out that there is no evidence for the attribution to Leonardo (even ultimately) of the alphabet now in the Newberry Library, Chicago (Fig. 19). On this see above, note 1.

16. On this point see Morison, *loc. cit.*

17. *Theorica et Practica de modo scribendi*, Venice, 1514.

18. Meiss, *op. cit.*, p. 64.

19. See G. Dehio, "Zur Geschichte der Buchstabenreform in der Renaissance," in *Repertorium für Kunstwissenschaft*, IV, 1881, pp. 269–79, and E. Crous, *Dürer und die Schrift*, Berlin, 1933, p. 11. The text for one letter has been published (by Dehio), but none of the letters themselves. Dehio proposed that the text was copied from a lost late fifteenth-century treatise, probably by Leonardo, and also was the source of the ideas of Pacioli, Dürer, and Feliciano, whose *ars litteraria* he dated after 1481.

It is to be hoped that this manuscript, apparently important, will soon be studied adequately. Crous, whose book became available to me only after my own was in galleys, gives a short account of the alphabetical treatises. His statements of fact are sometimes incorrect, as, for instance, about Moille's preferred ratio. He is the only writer who comments on the prismatic letter, wondering whether the innumerable examples in printed books of the 'nineties derive from Feliciano.

20. See E. Panofsky, *Albrecht Dürer*, Princeton, 1943, I, p. 266 ff. See also p. 258 for a discussion of Dürer's alphabet.

21. See S. Morison, *op. cit.*, p. 22. See also A. Christian, *Débuts de l'Imprimerie en France*, Paris, 1905, p. 83 and plate opposite p. 275. Already in 1529 Geofroy Tory utilized a more elaborate system of coordinates than his Italian predecessors, aiming at a more precise mathematical determination of the letters (Fig. 24). Cf. *Champ Fleury*, Paris, 1529 (ed. G. Cohen, Paris, 1931).

Computer Recognition of Hand-printed Text

John H. Munson

This paper describes the procedures and results of a project aimed at the computer recognition of relatively unconstrained hand-printed texts. Scanning, feature-extraction, and character classification techniques are described. Novel approaches investigated include a feature-extracting preprocessor consisting entirely of local edge detectors, the use of multiple-valued confidence indicators both before and after classification, the combining of independent preprocessor-classifier systems in parallel to achieve improved character-recognition accuracy, and the use of application-oriented context analysis. Two large files of hand-printed data are described, and results concerning their legibility are given. An extensive bibliography in hand-printed character recognition is included.

Introduction and Background

Among the many subject areas in the field of pattern recognition, the recognition of machine-printed and hand-printed alphanumeric characters has perhaps been the classic example to which people have referred in exemplifying the field. Interest in character recognition has long run high; an extensive literature in hand-printed character recognition alone dates back to at least 1955.[1–36]

In recent years the recognition of machine printing has become a commercial reality. Following the introduction of the highly controlled E13B magnetic font by the banking industry, several advances in optical character recognition (OCR) capability have been brought to the market-place. The trend of these advances is toward the acceptance of broader and less controlled classes of input: from single, stylized fonts to multi-font capability; from high-quality copy to ordinary inked-ribbon impressions, and even to multi-part carbons of surprisingly poor quality. Still, in contrast to hand printing, the approaches to OCR have been able to rely on the lack of gross spatial distortions in the character images, and to make considerable use of templates.

Progress in the off-line recognition of hand printing has been slower. The problem is intrinsically harder than that of OCR, as reflected in the fact that the human recognition error rate for isolated, hand-printed characters is many times higher than for machine printing. The great spatial variability of hand-printed characters has led many researchers to explore non-template methods for recognition.

Thus, the major effort of many researchers has been the exploration of unique methods of preprocessing, or feature extraction, applied to the hand-printed character images. Dinneen,[1] in one of the earliest papers, investigated local averaging and smoothing operations to improve the quality of the character image. Similar operations have appeared as a part of many other approaches.[4,7] Lewis,[15] Uyehara,[21] Stern and Shen,[23] and Rabinow Electronics[31] have used schemes in which the sequence of intersections of a slit scan with the character image, or the equivalent, gave rise to features for classification. Lewis[15] was one of the relatively few to emphasize the use of multiple-valued rather than binary-valued features, an ingredient we have found important in our own work.

Singer[12] and Minneman[30] employed a circular raster, which can facilitate size normalization and rotation invariance. Unger,[7] Doyle,[9] and Glucksman[27] have emphasized features derived from shape attributes such as lakes, bays, and profiles. The building up of a character representation from component elements matched to the image, such as short line segments or portions of the boundary, has been attempted by Bomba,[4] Grimsdale, *et al.*,[6] Kuhl,[19] and Spinrad.[26] Correlation techniques have been tried by Highleyman[13] and Minneman.[30] Contour-following with a captive flying-spot scan or its simulated equivalent has appeared in the work of Greanias, *et al.*,[20] Bradshaw,[22] and Clemens.[28] The work of Greanias, *et al.*,[20] is especially significant because it led to the method used in the IBM 1287 character reader.

Other workers have placed greater relative emphasis on classification techniques and on the selection of features from a feature set or pool. Chow[16,29] has long worked with statistical classification methods. Bledsoe and Browning[3] and Roberts[8] applied adaptive

procedures to features obtained from more or less random connections with the image raster. Uhr and Vossler[11] performed an important pioneering study of a program that "generates, evaluates, and adjusts" its own parameters. Not surprisingly, however, the automatically generated features were confined to simple, local templates.

The recognition of characters printed subject to specific constraints (such as guide markers appearing in the printing area) has been studied by Dimond,[2] Kamentsky,[14] and Masterson.[18]

It may be said of most of these investigations that they were in the academic, rather than the practical, realm. In general, the methods were never tested against a body of real-world data large enough to give some estimate of their performance in a practical situation. This probably reflects a common emphasis on checking out a preprocessing scheme rather than attacking a particular application problem; it certainly also reflects the labor and equipment requirements involved in collecting and controlling a significant body of data. An exception to this general statement is the work of Highleyman and Kamentsky in the early 1960's, in which they used data files numbering in the thousands of characters.[13,14] Also, several files each containing many thousands of characters of graded quality were gathered in conjunction with the development of the IBM 1287 character reader and are currently in use at IBM and in our group. Bakis, *et al.*[35] describe these data, on which they and others at IBM have performed extensive experiments.

The use of context to improve recognition performance, which figures prominently in our own work, was discussed briefly by Bledsoe and Browning,[3] but otherwise has received scant attention in the past. Some studies have been carried out under simplifying assumptions such as Markov dependence in digrams and trigrams.

Chodrow, *et al.*,[31] surveyed hand-printed character-recognition techniques in 1965 and discussed at some length the procedures of Clemens,[28] Greanias, *et al.*,[20] and Rabinow Electronics. The book *Pattern Recognition* by Uhr[32] reprints a number of the important source papers[3,6,8,11] and contains a well written survey. An early progress report on the work described herein was given by Munson.[36]

Recently, commercial organizations have announced the capability to read off-line hand printing. At the date of this writing (early 1968), one system (the IBM 1287 optical reader) has achieved pilot production operation. The 1287 reader can read the ten numerals and five letters. Another system is announced to have full alphanumeric capability.

A common characteristic of the announced systems is that they are intended to work with hand printing of very high quality, produced by coders who have undergone training in the skill of printing for machine recognition. If individual characters must be recognized with, say, better than 99.9% accuracy in order to yield usable document acceptance rates, this type of training is clearly required. Some experiments that will be described in the next section show that humans cannot recognize isolated characters printed by an untutored population with any rate approaching the required accuracy.

In our work, we have taken the alternative approach: given text from an untutored coder, in which the individual characters cannot be recognized (by man or machine) with high accuracy, contextual analysis is used to reduce the error rate. Every form of text has its own contextual structure, which is utilized by humans in a complex, largely unconscious process. We have therefore emphasized the following points in our research: the establishment of large hand-printed data files of known quality; the choice of a well defined character alphabet and textual situation (FORTRAN program texts) as a vehicle for study and the reporting of results; the use of multiple approaches to preprocessing; context analysis to improve recognition; and the preservation of non-binary confidence information between the preprocessor and classifier and between the classifier and the context analyzer.

In a companion paper,[37] Duda and Hart describe the use of programmed contextual analysis in the recognition of FORTRAN program texts. The present paper will therefore concern itself only with the problem of recognizing individual characters.

Problem Definition

In a recent paper, the author has argued that there is an infinity of character-recognition problems, and that recognition results are meaningless as they are often reported in the literature, without an adequate description of the problem being treated.[38] Accordingly, we shall try to describe the two recognition problems dealt with in this paper thoroughly enough that the reader can form an intuitive opinion of the difficulty of the problems.

We must first distinguish between off-line character recognition from a printed page, and on-line recognition, in which the characters are generated by a light pen, RAND tablet, or similar device.[24,33,34] On-line recognition is much simpler because the data provide a nearly exact trace of the path of the writing instrument and give accurate stroke-position and time-sequence information. Furthermore, an error rate of as much as 5% may be considered acceptable, because each character can be classified, displayed, and corrected immediately by the writer if it is wrong.

The recognition of hand-printed characters should also be distinguished from that of cursive (connected) script.[25] The separation of the printed characters and the fact that each belongs in a well-specified category obviate the "segmentation problem" that makes cursive-script recognition much more difficult.

Within the framework of off-line block hand printing, the difficulty of a particular problem is still affected by many variables: the size of the alphabet; the "standard" forms of the individual characters and the degree of constraint placed on their formation; the size, spacing, and arrangement of text on the page; the writing instrument(s); the number of writers; their training and motivation; and the (fixed and time-varying) characteristics of each individual writer. To illustrate the variability of hand printing, we may cite several instances of human recognition rates on samples of hand printing. Neisser and Weene reported a 4.1% average error rate on characters printed by visitors at the front gate at Lincoln Laboratory.[10] With all subjects voting together, the error rate was 3.2%. We have reported an error rate of 11% on the well-known quantized character set collected by Highleyman, which suffers from crude quantization of the characters.[39] On the multiple-coder data file used in our experiments and described below, the error rate was 4.5%; on the single-coder file, 0.7%. Finally, present commercial systems are intended to operate with character error and reject rates on the order of 0.1% to 0.01%.

The most significant determinants of hand-printing quality are the training and the motivation of the printing population. Our choice in the work described in this paper was to treat data from an essentially untutored, moderately motivated population, represented by computer users who hand-code program texts for keypunching. Such a coder has typically received no instruction in printing, beyond a few rules about slashing or crossing characters to avoid such confusions as I-1, O-zero, and 2-Z. He does receive feedback of the results from prior keypunching jobs, which motivates him to maintain (perhaps grudgingly) a certain level of legibility. Thus, while this printing is far sloppier than that allowed by presently announced recognition systems, it is more legible than that produced by the general public while, for example, addressing mail.

Two files of data were used in the experiments reported in this paper, a multiple-coder file and a single-coder file. The characters in both files were hand-printed on standard general-purpose coding sheets obtained from the Stanford Research Institute computer center. The cells on these sheets measured $\frac{1}{4}$ inch high by $\frac{3}{16}$ inch wide, with no extra spacing between cells. A thin-lead mechanical pencil with an HB (soft) lead was used, after brief experimentation indicated that no other conventional writing instrument gave crisper images when viewed through our input system. (A pencil is the preferred instrument because it facilitates erasure.) The coder was free to use whatever character size he found natural.

The 10 numerals, the 26 upper-case letters, and the symbols [=*/+-.,$] comprised the alphabet of 46 characters. This is the basic FORTRAN alphabet, with brackets substituted for parentheses in accordance with the convention associated with our computer system at the time. The blank was not treated as a character category, the recognition of blanks being more a function of a document-scanning subsystem than a pattern-recognition problem. We instructed the coders to print zero with a diagonal slash and Z with a midline slash, and to put crossbars on the letter I. Numeral 1 was to be without serifs; several coders, however, added serifs. Other choices were left to the individual, such as open versus closed 4, the crossbar on J, and the number of verticals in $.

Multiple-Coder File. Printed data from 49 individuals were included in the multiple-coder file. Each person was asked to print several 46-character alphabets on a coding sheet (at one sitting), and the first three alphabets from each sheet were taken for the file. The data from the first 32 persons (96 alphabets, 4416 characters) were used as training or design data during the experiments, and the data from the remaining 17 persons (51 alphabets, 2346 characters) for test. The coders of the training data were all personnel of the author's laboratory and the computer center at SRI. The coders of the test data were eight from SRI and nine from the US Army Electronics Command, Fort Monmouth, N.J. Any cross-country bias in printing styles is probably small compared with individual differences.

Portions of several of the test alphabets are shown in Figure 1. The coders were asked to print naturally, being neither especially casual nor especially meticulous. However, it is obvious that data gathered this way are not candid; they are probably better than data from actual coding sheets prepared for keypunching. Unfortunately, it was not feasible for us to process candid data from a number of people using a variety of coding forms and languages.

Five human subjects were asked to classify the characters in 17 of the test alphabets—one from each coder—viewing the quantized images (see the section on scanning) in isolation and in random order on a cathode-ray tube display. The error rates ranged from 3.0% to 6.4%, with an average of 4.5%. Taking a plurality vote among the five responses, the error rate was 3.2%.

Single-Coder File. Experiments were also performed with a single-coder file, in order to investigate the improvement in performance resulting from allowing the recognition system to specialize in the printing of a single individual. This file contained 1727 training characters and 1042 test characters. The training set included 15 alphabets (690 characters) of the type collected for the multiple-coder file. The remaining 1037 training characters were taken from FORTRAN text on coding sheets, as were the 1042 test characters. The 15 alphabets were included in the training set to ensure adequate representation of all the character categories, since their appearance in actual text was haphazard.

The text characters were taken from FORTRAN coding sheets prepared by the author in the course of actual program development, some months before the recognition experiments were performed. The coder corrected major malformations of characters as he noticed them, but avoided printing with unnatural care. Thus, while these data are not candid, it is felt that they closely model a realistic situation that would be obtained if one tried to serve a coder who was making a minimal effort to assist the system.

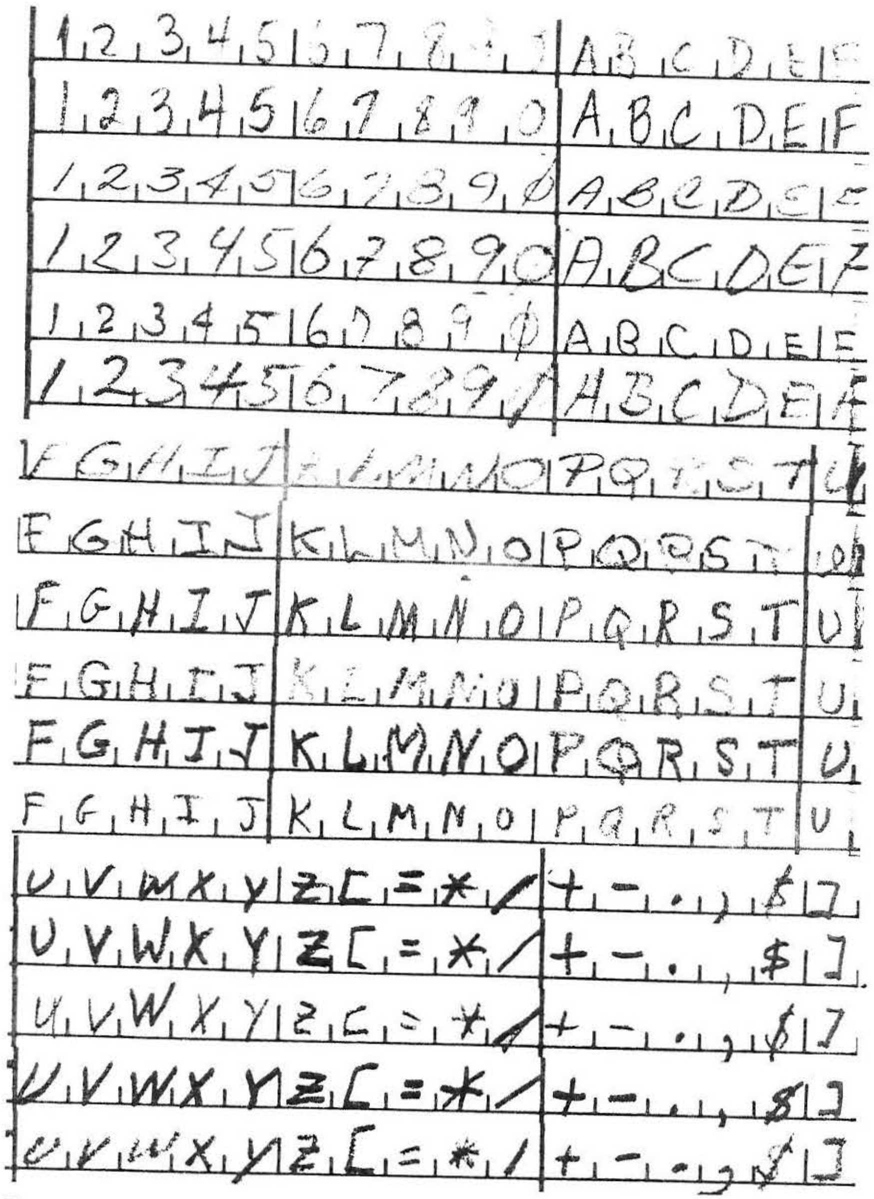


Figure 1. Portions of several multiple-coder test alphabets.

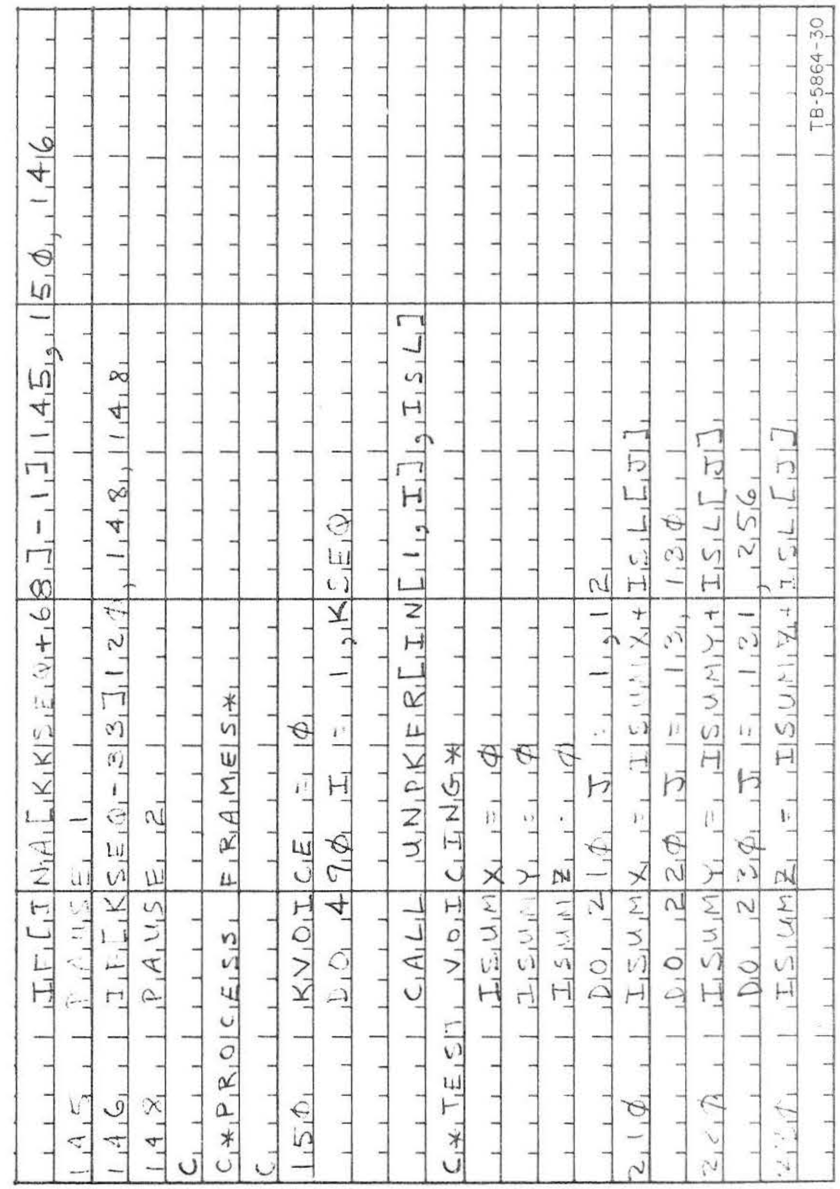


Figure 2. A sample of the single-coder test data.

A sample of the test data is shown in Figure 2. We may describe these characters as being quite legible to humans but not highly regular. Ten human subjects were asked to classify the test characters. The average error rate was 0.7%. Taking a plurality vote among the 10 responses, the error rate was 0.2% (two errors in 1042 characters).

Scanning

The hand-printed characters were scanned from the source documents (the coding sheets) by a vidicon television camera fitted with a close-up lens and operated under the control of an SDS 910 computer. Each document was mounted in a concave cylindrical holder so that, as the camera panned across the document, the viewing distance and hence the image scale remained constant. The field of view was approximately one inch square. The camera generated a standard closed-circuit television waveform, which was quantized to two levels (black/white) by a Schmidt trigger and sampled in a raster of 120 × 120 points.

The document was illuminated by four floodlights mounted around the TV camera. A colored filter was placed over the camera lens, to suppress the colored coding-sheet guidelines appearing on the document. The guidelines could have been used for locating the characters, but we preferred to strive for a free-field character-locating procedure that could ultimately handle between-the-lines corrections or coding on a blank sheet of paper. Also, without a color-sensitive input system, separating the guidelines from the characters where they crossed or coincided could be a major problem.

The field of view was chosen so that a single character image was usually a little less than 24 points high and about 15 points wide. The computer began the scanning by reading in a 120 × 120-point picture containing, in general, several character images. A scanning routine then proceeded approximately horizontally through the picture, finding and isolating character images. Provisions were included for tracking a line of text, and for accepting multi-part character images such as equal signs and characters with unconnected crossbars. When the scanning routine got to the right of the 120 × 120 picture, it requested the camera to move to the right and input another picture.

As each character was isolated, it was placed in a standard 24 × 24 raster format (Fig. 3). No corrections for magnification or rotation were applied. The BCD code of the character was entered manually


```
**************************
*                 0      *
*         0 000000000    *
*        0000000000000   *
*      0000000     000   *
*     00000000     000   *
*      00 000     000    *
*         000     00     *
*         000    000     *
*        000    000      *
*        000   000       *
*        000  0000       *
*        0000000         *
*       0000000          *
*       000000000        *
*      000     0000      *
*      000     0000      *
*      000       00      *
*      000       00      *
*     0000      000      *
*     000      0000      *
*     000      000       *
*   00000     000        *
*   0000    00000        *
*  00000000000           *
**************************
```

Figure 3. A hand-printed character in the standard 24 × 24 format.

at the console typewriter and attached to the character record, for subsequent use in the training and testing procedures. The two files (single-coder and multiple-coder) of quantized 24 × 24 black/white character images served as the starting point for all subsequent processing. We hope to make these files available to other researchers through the efforts of the Subcommittee on Reference Data Sets of the Committee on Pattern Recognition of the IEEE Computer Group.

Our scanning setup was "strictly experimental." It was an inexpensive substitute for the sophisticated optical scanner and mechanical transport required for a high-volume production system. Although the scanning routine enabled us to gather the thousands of quantized characters in our data files, it was never capable of running without an attendant to rescue it from its errors. These were due to badly non-uniform sensitivity across the field of view (common in vidicon tubes), which made it impossible to set a single quantization threshold valid throughout the field, and to the lack of precise knowledge of the position of the TV camera. (Incidentally, by solving these problems, it should be possible to create a low-speed, inexpensive automatic scanning system along the lines of the one described above.)

Other files of digitized hand-printed data, supplied through the courtesy of W. Highleyman and researchers at IBM Corporation and Recognition Equipment, Inc., have been processed merely by converting them to our standard 24 × 24 format. In some cases, this has required changing the size of the character raster by copying or deleting rows and columns.

Preprocessing

The term "preprocessing" has acquired a variety of meanings. We use it here to refer to the specific activity of feature extraction: The calculation, from the (quantized) character image, of a set of numerical feature values that form the basis of subsequent pattern classification.

Two preprocessing methods were used in these experiments. The first, embodied in a computer program called PREP, was a simulation of a previously constructed optical preprocessor capable of extracting, in parallel, 1024 optical correlations between a character image and a set of photographic templates, or masks.[40] The second, a program

called TOPO, extracted a large number of topological and geometric features of the character image.

The PREP Preprocessor. The PREP program performed edge detection on the 24 × 24 quantized images through the use of edge-detecting mask pairs, or templates. Each mask pair consisted of two 2 × 8 rectangles of points, adjacent to each other along their long edges. One of the masks was given positive weight, the other, negative, and a threshold was set such that if the positive mask encountered six more figure points than the negative one, the binary response of the mask pair was ON (Fig. 4).

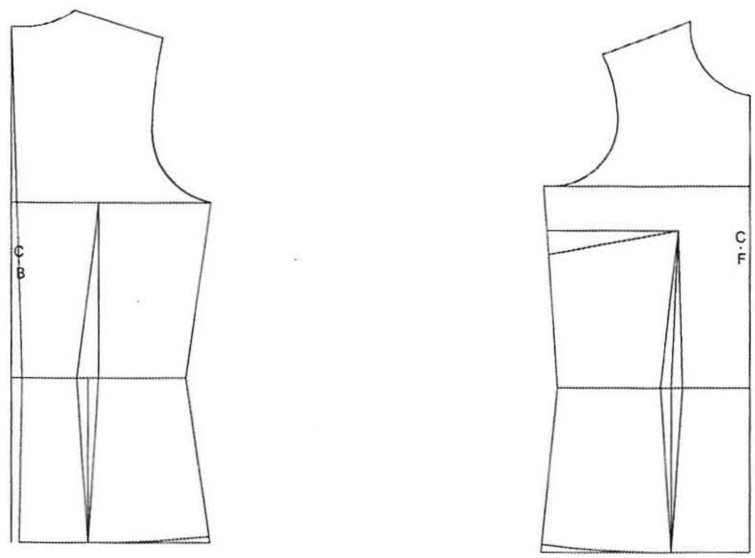
To provide a limited degree of translation invariance, the responses of five such mask pairs were OR-ed together to give a single binary component of the output feature vector. The five mask pairs in a group had the same orientation and were in the same region of the 24 × 24 field. Nine regions were allotted to each of the four major compass directions, and six regions were allotted to each of the eight secondary directions (at 30° intervals). Thus, the complete feature vector consisted of 84 binary components, and the significance of a typical component was, "an edge oriented north-of-west has been detected in the left central region of the field." Figure 5 shows a computer display in which the lines are normal to edges detected in a sample of the numeral 2. The lines emanate from 15 loci representing the allotted regions.

Each quantized image was presented to the PREP preprocessor nine different times, first in the center of the 24 × 24 field, then in the eight positions formed by translating it vertically and/or horizontally by two units. Thus, for each pattern, a set of nine 84-bit feature vectors was formed. The use of these multiple-view feature vectors to improve classification performance is described below.

The TOPO Preprocessor. The TOPO preprocessor was a sizeable collection of computer routines assembled to extract topological and geometric features from the character image. In general, these features described the presence, size, location, and orientation of such entities as enclosures and concavities (lakes and bays) and stroke tips in the character.

TOPO began with a single connected character image in the 24 × 24 field. (The equals sign was sought out in advance, and treated

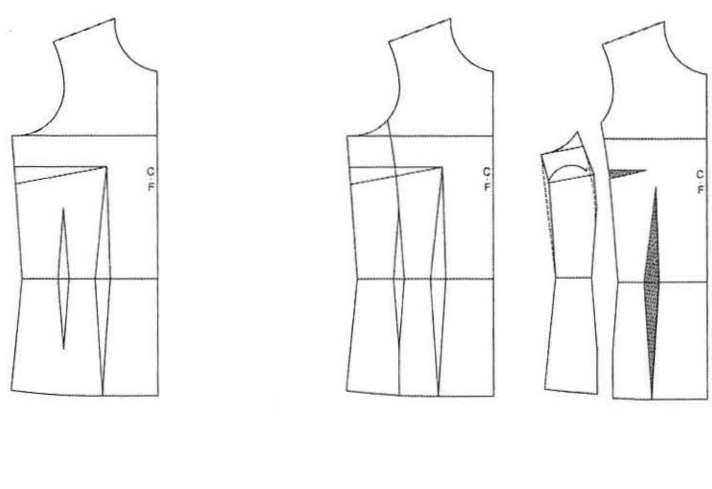
Blouse Foundation

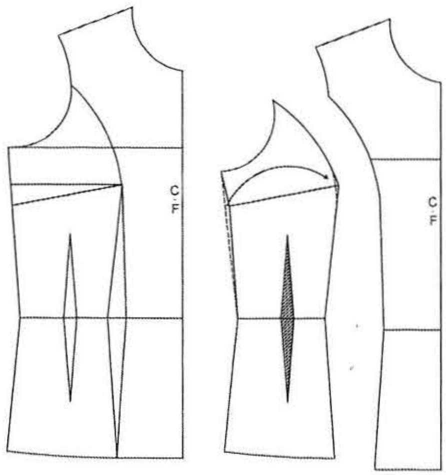


Princess Line Blouse Foundation

How to shift the blouse into a slim fit princess seam blouse.

Draw the princess style line from the armhole to the hem and blend into the large or small waist dart (depending on desired fit). Then close the bust dart.



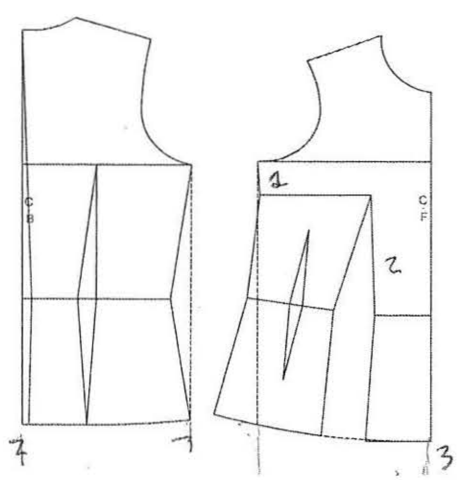


Loose Fitting Blouse

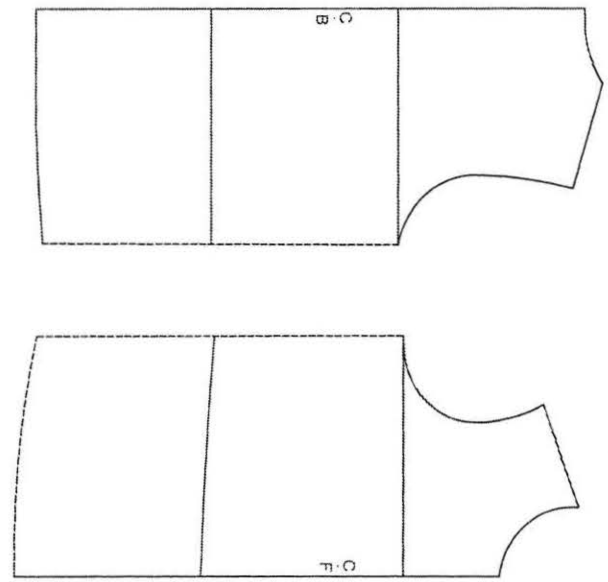
Square down a straight line from the center back neckline and armhole.

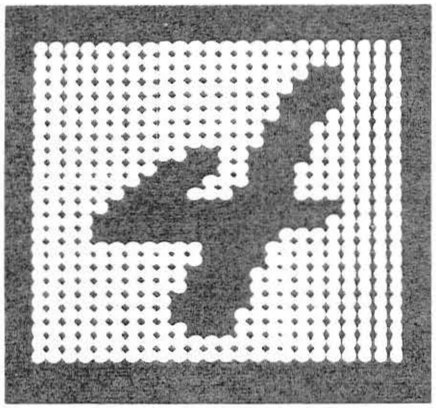
Close the front bust dart,and transfer the difference by opening the larger waist dart.

Draw down a straight line from the armhole.

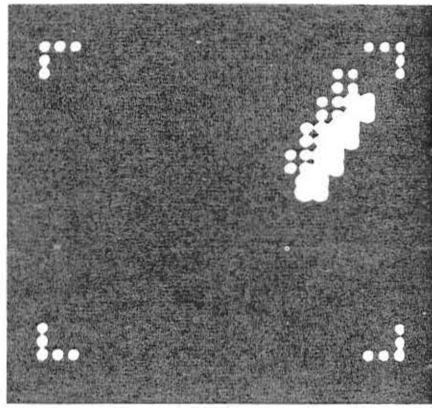


Re-draw the new patterns ignoring all the darts.

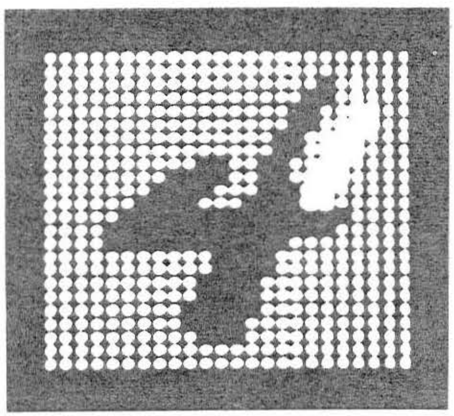

C·B
C·F



(a)



(b)



(c)

Figure 4. Edge-detecting masks in PREP: (a) quantized character image; (b) an edge mask; (c) character and mask together.

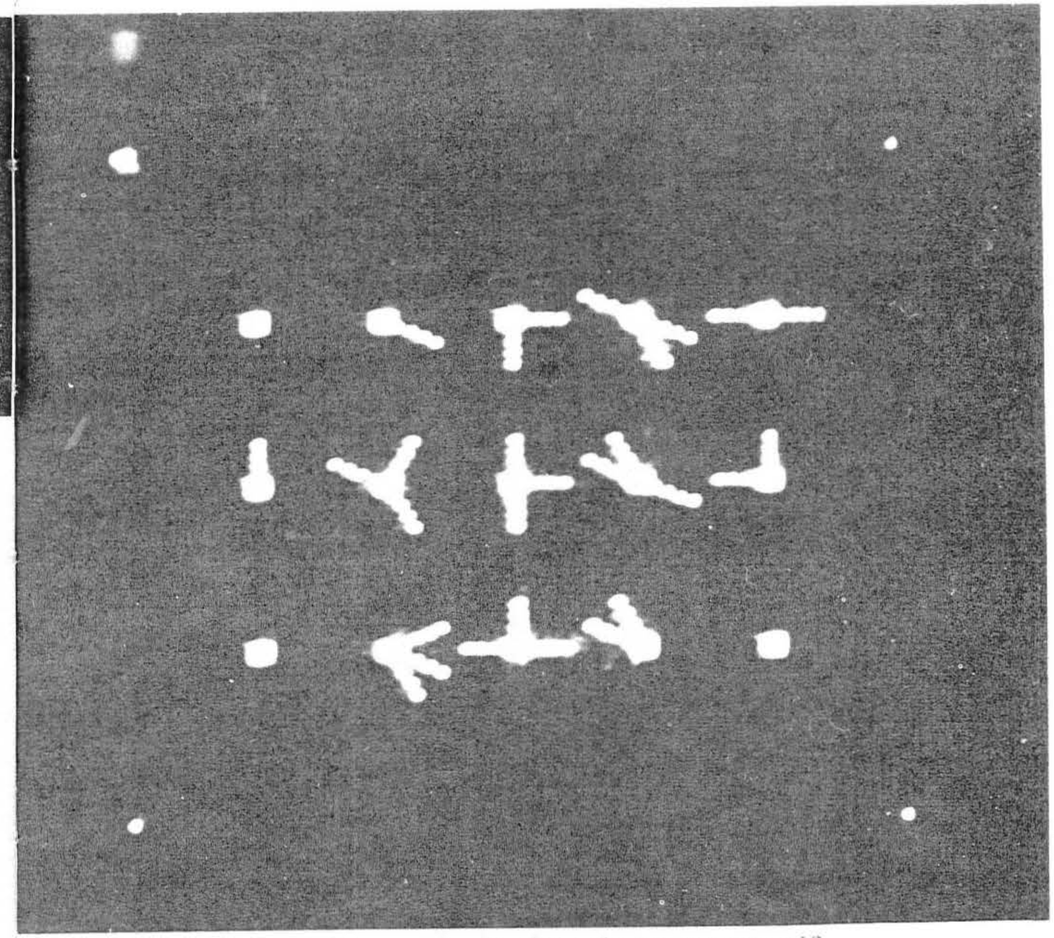


Figure 5. Responses of the PREP edge-detecting mask groups to a numeral 2.

as a special case. Other unconnected figures were forcibly joined by growing a bridge between the individual connected regions. If this failed, the lesser region(s) were discarded.) The *perimeter* of the figure was first found (Fig. 6). The perimeter was defined as a list of figure points, beginning with the bottommost of the leftmost points of the character figure, found by stepping along the edge of the figure and keeping the figure always at the right hand and the ground (non-figure) at the left. The perimeter has the property of including all figure points that are 8-adjacent (adjacent horizontally, vertically, or diagonally) to ground points outside.

Next, the *convex hull boundary* (CHB) of the figure was found (Fig. 7). The CHB of a two-dimensional figure may be thought of as the outline of a rubber band stretched around the figure. In the case of a quantized figure, some arbitrariness is required in the specification of the CHB, because a straight line between two points on the image grid does not generally fall on exact grid locations. We defined the CHB to include all the extremal points of the character image, represented by letters other than "X" or "O" in Figure 7. In between these extremal points, the CHB was to follow as straight a path as possible, but never falling outside of the theoretical straight line connecting the extremal points. Keeping the CHB to the inside reduced the number of small, insignificant concavities found subsequently. To find the extremal points in the CHB, it was only necessary to search among those perimeter points at which the perimeter turned to the right.

After the CHB was obtained, the concavities and enclosures of the character image could be found quite readily using computer routines that simulated Boolean and connectivity operations performed in parallel over the entire 24 × 24 field. Let the *border* consist of those ground points in the outermost rows and columns of the 24 × 24 field. Let an image be formed consisting of the ground, minus the CHB. The portion of this image that is not connected to the border lies within the CHB and consists of the concavities and enclosures of the character. Those regions that are connected to the border by a path of ground points (including ground points in the CHB) are concavities; those regions that are not are enclosures within the figure. The character in Figure 7 contains two concavities and two enclosures.


```
**************************
*                  X     *
*         X XXXXXXOXX    *
*        XOXOOOOOOOOOX   *
*      XXOOOOO     OOX   *
*     XOOXOOOO     OOX   *
*      XX XOO     OOX    *
*         XOO     OX     *
*         XOO    OOX     *
*        XOO    OOX      *
*        XOO   OOX       *
*        XOO  OOXX       *
*        XOOOOOX         *
*       XOOOOOX          *
*       XOOOOOOXX        *
*      XOO      OOXX     *
*      XOO      OOOX     *
*      XOO        OX     *
*      XOO        OX     *
*     XOOO       OOX     *
*     XOO       OOOX     *
*     XOO       OOX      *
*    XXOOO     OOX       *
*    XOOO    OOXXX       *
*  XXXXXXXXXXX           *
**************************
```

```
**************************
*                  E     *
*           DxXXXXXX0XF  *
*          X00000000000G *
*        CX00000     00X *
*       B0000000     00H *
*       x00 000     00X  *
*       x   000     00x  *
*       x   000    000x  *
*       x  000    000 x  *
*       x  000   000  x  *
*       x  000  0000 x   *
*      x   0000000   x   *
*      x  0000000    x   *
*      x  000000000  x   *
*      x 000      0000x  *
*      x 000      000X   *
*      x 000        0X   *
*     x  000        0X   *
*     x 0000       00X   *
*     x 000       000I   *
*     x 000       00X    *
*     X0000      00X     *
*     X000     00XXJ     *
*    AXXXXXXXXXK         *
**************************
```

Figure 6. Hand-printed character with perimeter points marked X.

Figure 7. Character with convex hull boundary (CHB).

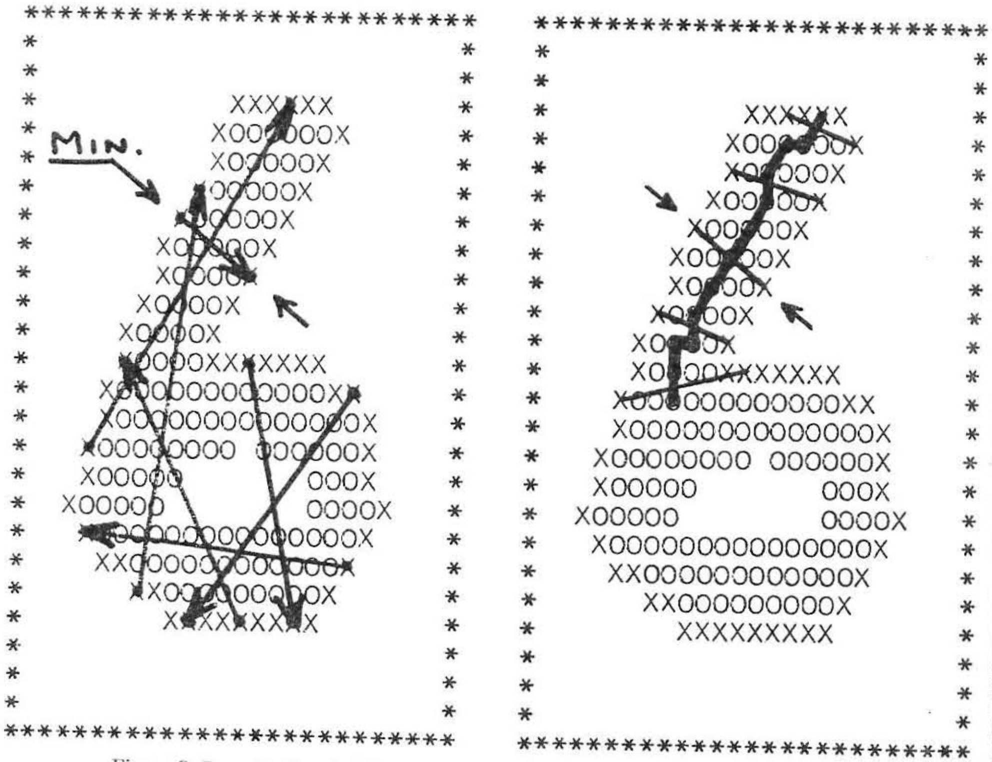


Figure 8. Spur-finding. (a) finding the spur tip; (b) tracing the spur.

Multiple concavities and/or enclosures were extracted all at once in a single 24×24 array by the parallel operations. They were then separated (again using the connectivity operations) and sorted by size for subsequent use.

The *spurs* of a character are those strokes that end in an isolated tip. Ideally, the letter X has four spurs, the letter O, none, and the letter S, one spur with the special property of having a tip at each end. The list of perimeter points was used to find the spurs. Consider two pointers moving down the list of perimeter points, with one pointer ahead of the other by, say, 15 places. As the pointers moved, we calculated the Euclidean distance between the two perimeter points indicated by the pointers. Some of these distances are represented by arrows in Figure 8a. Most of the time this distance would be approximately 15 units. A sudden decrease of the distance between the two points to a minimum that was less than half its usual value indicated that the perimeter had gone around a sharp bend—i.e., had gone around the tip of a spur. The position of the spur tip, indicated by the perimeter point halfway on the list between the two minimum-separation points, was the primary attribute of the spur used for forming features.

Once a spur was found, it could be traced by the "caliper method" (Fig. 8b). Imagine that the legs of a pair of calipers are placed at the two minimum-separation points. The calipers are then "slid" along the spur by stepping the legs of the calipers along the perimeter, away from the tip. The calipers are moved as far as they can go without having to be spread by more than, say, seven units. In some cases, such as the numeral 6, the calipers will be obstructed by the body of the figure and must stop. In other cases, such as the letter S, the legs of the calipers will travel all the way along the figure and meet at the far end, indicating a "single-stroke" figure. The midpoint of the moving calipers traces out the backbone of the spur, and a list of the midpoint positions can be stored to represent the spur (the heavy line in Figure 8b).

Another set of character attributes found in TOPO and used for feature generation were the *profiles* of the character image. The profiles were four lists, of 24 entries each, specifying the first row (or column) in which a figure point was encountered in each successive column (or row) as seen from the top, bottom, left, and right. The profiles were the basis of a number of specialized feature calculations, designed to discriminate among particular categories, that evaluated such properties as the width of the character at various levels, the number of reversals of direction in a profile, and discontinuities in the profiles.

Numerical Feature Calculation in TOPO. After the topological and geometric components of the character image—concavities, enclosures, spurs, profiles, etc.—were extracted, it remained to convert them to numerical components of a feature vector suitable for subsequent classification by an adaptive machine. This task was beset with several conceptual and practical difficulties that may not be obvious at first.

In TOPO the task was carried out in two steps. First, *descriptors* (individual numerical quantities) were derived from the information at hand. Second, *features* in a standard form were calculated from the descriptors.

Each descriptor had to be chosen so that it always represented a unique characteristic of the character image. For example, suppose that one descriptor were to represent the vertical position of the rightmost spur tip. Such a descriptor would help to discriminate, for example, between T and L. But this descriptor would give unpredictable results for characters such as C, E, and [, depending on which spur extended farther to the right, and would probably be detrimental to the classification of characters in these categories. In addition, there is the problem of vacuous descriptors: What value do we assign to the above descriptor in the case of a letter O?

In TOPO, these problems were countered by a careful choice of the definition of the descriptors. In many cases it was possible to devise a descriptor that was always well defined. For example, if a spur-descriptor is put in the form, "to what extent is there a spur in the upper righthand corner," it is defined for any number of spurs and can properly be given its minimum value for a figure with no spurs at all. In addition, this form of definition (unlike the preceding one) has the important property of *continuity*: deformations of the character image that move the spurs by small amounts always cause small changes in the value of the descriptor. In another paper, the author has argued that the preservation of continuity is important throughout the various stages of the pattern-recognition process.[38]

As the final step in TOPO, the actual features (the numerical components of the feature vector for classification) were calculated from the descriptors. A first requirement on the features was that they be of comparable magnitudes, so that none would dominate the sums formed in the pattern classifier. Thus, the features were all given a standard range of zero to 100. (Note that these features were multiple-valued, whereas those from the PREP preprocessor were binary.)

A second, heuristic requirement on the features was that they emphasize the significant differences among character classes. In a two-category classification problem, it is feasible to analyze the discriminating power of a feature statistically (or even by inspection), and to adjust the transformation from descriptor to feature so as to maximize this power. In our 46-category problem, we could only guess at reasonable transformations. In any case, one should not expect the feature to be a simple linear function of a descriptor.

The derivation of features in TOPO may be indicated by an example. Consider a descriptor, MCONC(up), which is a measure of the presence of an upward-facing concavity in the character. For a flat-topped or round-topped character, such as T or O, MCONC(up) should have the value zero. For a character such as U or V, MCONC(up) should have a value of eight or greater. For a Y or an open-topped 4, however, we should only expect values of five or greater. Owing to the linear nature of the dot-product units used in the pattern classifier, it is impossible for a single feature proportional to MCONC(up) to discriminate between Y and T, for example, without treating U as a "super-Y." We actually require *two* features—one that "switches" in the range 0 to 5 and one that does so at a higher range.

The two transformations that derived features from MCONC(up) in TOPO are shown in Figure 9. There were two such features corresponding to each spur descriptor and concavity descriptor in TOPO. In all, TOPO produced 68 features: 16 for the spurs, 16 for the concavities, 8 for the enclosures, 6 for overall character size and shape, and 22 resulting from special calculations about the width of the character at various levels, discontinuities in the profiles, etc. Each feature was calculated from a numerical descriptor by a transformation arrived at by inspection.

It should be evident from the foregoing description that the

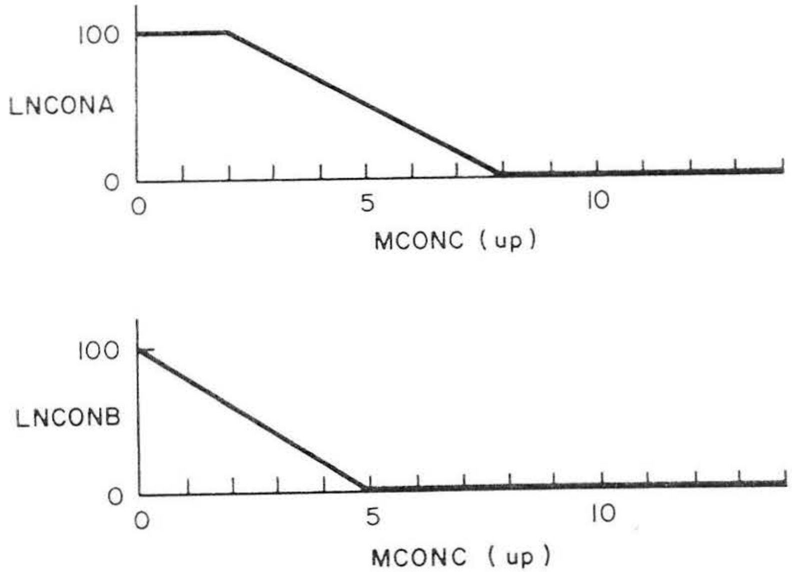


Figure 9. Two transformations that derive features from a concavity descriptor.

development of TOPO was a cut-and-try affair. The extraction of topological entities and the generation of descriptors and features were continued only as far as patience permitted. For example, a feature to look for structure within an enclosure and help discriminate between O and Q was never implemented. It is the author's opinion that the generation and selection of features for pattern classification, especially in the multi-category case, is the greatest problem area in pattern recognition at the present.[38]

Classification

An adaptive pattern classifier, or learning machine, was used to classify the characters on the basis of the feature vectors generated by a preprocessor, either PREP or TOPO. The learning machine was of the piecewise linear (PWL) type, described by Nilsson.[41] The learning machine for these experiments was implemented by a computer program called CALM (Collected Algorithms for Learning Machines),[42] running on the SDS 910 computer, which simulated the action of the MINOS II hardware learning machine constructed earlier during this project.[40, 43, 44]

Briefly, a learning machine embodies a set of Dot Product Units (DPU's) that form the *dot product* (also called the inner product or vector product) between the incoming pattern, or feature vector, and a set of stored *weights*. The j^{th} DPU of the machine forms the dot product

$$S_j = X \cdot W_j = \sum_i x_i w_{ij}$$

between the pattern vector X and the weight vector W_j associated with the j^{th} DPU. In a PWL learning machine, a small number of DPU's are assigned to each of the 46 character categories. The largest dot product formed among the DPU's assigned to a category is taken as the *response* for that category.

The category responses may be utilized in two ways. If it is desired to explicitly categorize a character, the character is assigned to the category with the largest response. A *testing margin* or *dead zone* may be employed, so that any character for which the largest response does not exceed the second largest by the margin is classed as a reject. In the performance results listed below, the reject margin is not used. The performance scores are thus of the simplest possible type: percentage of successful classifications with no rejects allowed (response ties are broken arbitrarily).

Alternatively, if the goal is not to achieve a succinct performance measure but rather to use the character-classification information for contextual analysis, the responses may be used to obtain *confidence information*. The simplest confidence measure is the set of 46 responses from the learning machine, with a higher response indicating a higher confidence that the character belonged to the category in question.

To adapt a learning machine, a *training pattern* is presented, and the responses to that pattern are obtained. If the response in the true category of the training pattern does not exceed the largest response among the other categories by a value called the *training margin*, the DPU yielding the response in the true category is marked to be *incremented*, and that yielding the competing response is marked to be *decremented*. This is done by setting

$$a_{true} = 1 \quad ; \quad a_{competing} = -1$$

in the *adapt vector A*, and setting all the other components of A to zero. Adaptation of the weights is then performed according to the *fixed-increment error correction rule:*

$$W_j \leftarrow W_j + a_j \cdot D \cdot X, \quad \text{for all j.}$$

In other words, the pattern vector is added to or subtracted from the j^{th} weight vector, depending on a_j. D is an overall multiplying factor called the *adapt step size*, usually set to a small integer throughout a block of training. (Other methods of determining the responses and A and D lead to learning machines other than the PWL machine.)[41, 42]

The adaptation causes the subsequent dot product between the pattern vector and the weight vector to be changed by an amount

$$\Delta S_j = X \cdot (a_j \cdot D \cdot X) = a_j D |X|^2 \quad .$$

Since X^2 and D are always positive, the sign of a_j automatically determines whether the response (i.e., the dot product) of the j^{th} DPU with the pattern X is enhanced or reduced. Through this means, appropriate DPU's can be made to respond to certain patterns and ultimately to classes of patterns.

To perform a learning-machine experiment, the adaptive weights w_{ij} are initialized, usually to zero. The training patterns are then presented sequentially. The responses to each training pattern are formed, and if the classification is incorrect the machine is trained. One pass through the training patterns is called an *iteration*. Typically, repeated iterations through the training set are performed until the classification performance on the training patterns ceases to improve. At that time, the test patterns may be presented, and the classification performance on them recorded. This performance is generally taken as the measure of success of the learning machine on the task represented by the training and test patterns.

In dealing with the nine-view sets of feature vectors produced by the PREP preprocessor, the running procedure was modified slightly (Fig. 10). During training, one of the nine feature vectors representing a training pattern was selected quasi-randomly at each iteration. Thus, it took nine iterations for the machine to encounter each view of each pattern. The use of multiple views had the effect of "broadening" the training experience of the learning machine. During "nine-view testing," all nine views of each test pattern were

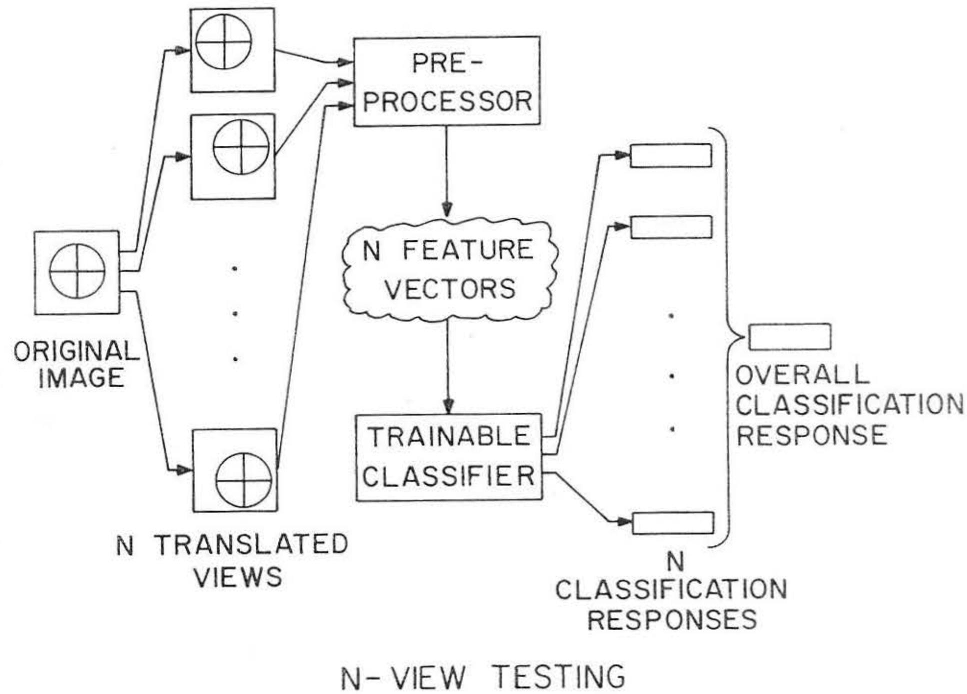


Figure 10. Multiple-view testing procedure.

presented and the nine responses in each category were added together to form cumulative responses that were used as the basis for classification. It will be seen that the redundancy achieved by accumulating the nine responses led to a significant improvement in performance. This technique has also been used successfully by Darling and Joseph in the processing of satellite photographs.[45]

Experimental Results

A series of experiments were performed on the single-coder and multiple-coder data files, using the preprocessors and learning machine described above. Experiments were run under four conditions.

In Condition 1, the characters were preprocessed by PREP, but only the one feature vector representing the central view of each pattern was used for training and testing the learning machine. Only the single-coder file was run under Condition 1.

In Condition 2, the characters were preprocessed by PREP in all nine views, and nine-view training and testing were performed as described above. A PWL learning machine with two DPU's per category was used in Conditions 1 and 2.

In Condition 3, the characters were preprocessed by TOPO, and the single feature vectors produced by TOPO were used for training and testing. Owing to computer restrictions, a learning machine with only one DPU per category was used. This is generally called a linear rather than a PWL learning machine, after the form of the discriminant functions in feature space.[41]

In Condition 4 the responses of the learning machines in Conditions 2 and 3 for each test pattern were added together and taken as a new basis for classification. This procedure was a way of harnessing the preprocessor-classifier systems of Conditions 2 and 3 "in tandem" in order to improve classification performance, in a manner analogous to the nine-view testing of the PREP feature vectors.

The results of the experiments are presented in Table I. The results show a significant improvement in performance for the case of nine-view training and testing over single-view training and testing, and further improvement with the combined system of Condition 4. The most important results can be summarized as follows:

Using the combined system, a correct character-classification rate of 97% (with no rejects) was obtained on independent test of relatively unconstrained hand printing in the 46-character FORTRAN alphabet, when the learning machine was allowed to specialize on data from a single coder. When the learning machine was trained on the printing of 32 coders and tested on the printing of 17 others, the correct classification rate was only 85%. These rates are for the isolated characters, without context.

A well-known set of quantized hand-printed character images (letters and numerals only) collected by Highleyman were also processed under Condition 2, yielding a test classification score of 68%. Previously reported classification methods, not employing preprocessing, had achieved scores of 58% or less. These characters are of very poor quality, being only 86% to 89% classifiable by humans. These results are described in Reference 39.

TABLE I. *Experimental Results on Two Files of Hand-printed Alphanumeric Characters*

Condition	*Preprocessor*	*Number of Iterations*	*Final Classification Scores* *Training Patterns*	*Test Patterns*
		Single-Coder File		
1	PREP, 1 view	10	99%	88%
2	PREP, 9 views	27	89%*	96%
3	TOPO	10	94%	91%
4	Combined	—	—	97%
		Multiple-Coder File		
2	PREP, 9 views	18	65%*	78%
3	TOPO	4	84%	77%
4	Combined	—	—	85%

*Single-view classification scores.

A large number of preliminary and auxiliary experiments, not described in this paper, were performed. In particular, during the development of the TOPO preprocessor, an attempt was made to use the features produced by TOPO in a binary decision-tree classifier. The results of this effort were very poor, because it was impossible to find features reliable enough to serve for dichotomization of the character classes.

For example, the presence of an enclosure was a useless feature, because quantization noise introduced some spurious enclosures, and other expected ones were lost because they were filled in or not completely formed. It thus appears to us that, for patterns with the variability of hand printing, an approach that considers all the features in parallel is a necessity.

The development of the TOPO preprocessor, the exploration of variations of the PREP preprocessor, and the running of classification experiments with different learning-machine configurations and different data files were all severely restricted by system limitations of two types. First, it was awkward to handle the necessary large data files on our computer, which had paper tape input/output and one magnetic tape unit. Second, all of the operations of scanning, preprocessing, and classification were performed in serial or at most in 24-bit parallel by simulations in the computer (an SDS 910, with

12K words of 24-bit memory and an 8μsec cycle time). It sometimes took days to accomplish the experimental runs. However, the flexibility, guaranteed reproducibility, and operational advantages of computer simulation compensated for the drawbacks. With a view toward practical systems, it may be noted that the operations of PREP and the learning machine, and even much of TOPO, are extremely well suited for implementation in parallel hardware.

Conclusion

This paper has been concerned solely with the classification of individual hand-printed characters, in isolation. To this end, performance scores based on the positive classification of each character have been presented, as the simplest and most understandable measure of performance. The end goal, however, is text recognition, not character recognition per se. The results presented here, including the scores for classification by humans, indicate that context analysis will be a necessary adjunct to character classification for the recognition of fairly unconstrained, untutored hand-printed text. The companion paper by Duda and Hart[37] describes our effort in context analysis. To assist context analysis, the classifier puts out not explicit classifications but lists of alternate categories and their confidences for each character. This may be viewed as a way of retaining additional valuable information generated by the classifier, under a continuous transformation (from feature space, through the learning machine, to the space of category confidence values). This preservation of alternative information is a vital aspect of context-aided text recognition, not to our knowledge previously discussed in the character-recognition literature.

In experimenting with a large body of actual data from an untutored hand-coding population, we are attempting to set a benchmark in an area not covered by the experiments in the former literature, nor by the present commercial developments. At the current levels of available computing power and cost, contextual analysis appears economically infeasible, at least for syntactically rich texts such as FORTRAN. However, if the progress of OCR is a guide, we may expect a pressure for the extension of recognition systems for hand printing to accept input from broader and less highly trained classes of coders. The character-recognition methods described in this paper and the context-analysis procedures described by Duda and Hart may then point toward systems of future importance.

Acknowledgments

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This paper was presented at the December 1968 Fall Joint Computer Conference in San Francisco under the title, "Experiments in the Recognition of Hand-printed Text: Part I—Character Recognition."

Illustration 1

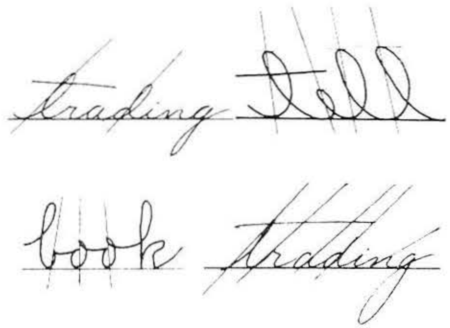
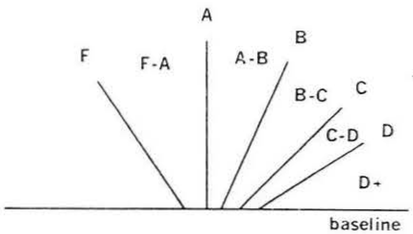
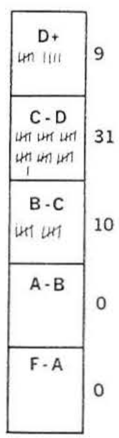


Illustration 2



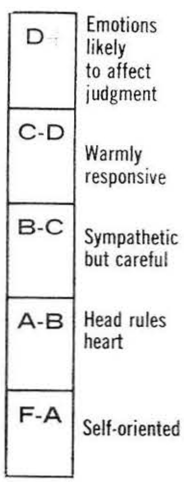
The Slant Guide

Illustration 3



Emotional Thermometer

Illustration 4



The slant of the upstrokes in your hand-writing is a dead giveaway to your "emotionality," according to the International Graphoanalysis Society. To take your own emotional temperature, find a sentence or two you wrote a day or so ago (it's better to use old writing, preferably on unlined paper). You'll need about 25 words. Draw a "base line" under the lines of writing. From this base line draw in lines following the angle of slant of 50 consecutive "upstrokes" (Illustration 1). Ignore the curves of the letters—make a straight line. Take a piece of transparent paper and make a tracing of the Slant Guide, (Illustration 2). Lay this guide on top of your marked-up writing. Each upstroke will fall somewhere between the lettered lines. Tabulate your marked strokes in a graph thermometer similar to Illustration 3. Most likely you will have strokes falling in three or more areas. Then check your "emotional score" by comparing the grouping of marked strokes in each area against Illustration 4.

Excerpted with permission from information received from the International Graphoanalysis Society, 325 W. Jackson Blvd., Chicago, Ill., 60606.

Recognizing the Marks on Paper

R. M. N. Crosby

Relatively little is known about how a child learns to read—i.e., what processes go on in his mind. In dealing with how the beginning reader learns to differentiate graphic symbols, this article considers several related problems: How does pre-school experience hamper the child in his initial discrimination of letter-like forms? How does a child learn to differentiate between letters? And between words? What is the correlation between reading and writing? Several reading research programs are discussed.

How does a child learn to read? That millions accomplish the difficult task every year does not negate the fact that little is known about how the child does it. We strongly suspect that if an intelligent child who is neurologically, culturally, and emotionally normal were left entirely to his own devices, but properly motivated to learn to read, he would discover how to do it himself. If given a few simple instructions, he would learn much more rapidly.

The vast majority of normal children will learn to read despite the methods of instruction used. It logically follows that if ideal teaching methods are used, the same child may learn more easily and at an earlier age. More importantly, the minority of children who are dyslexic may be helped over this necessary educational hurdle.

Some readers may be surprised that educators, psychologists, and physicians do not know how a child learns to read. True, it is known that if a child is taught by a look-say method, phonic method, linguistics, augmented roman alphabet, or some combination of these in a basal-reader, individualized, or experience approach to teaching, he learns to read—or most of them do. But no one knows what goes on in a child's mind. How does he differentiate between letters? How does he translate the graphic symbol into sound? How does he group letters into combinations and words and sentences so the reading process becomes more rapid and automatic?

While our knowledge of how a child learns to read is far from complete, it is vastly extended as the result of a study performed at Cornell University, *A Basic Research Program on Reading*,[1] done in co-operation with the Office of Education of the U.S. Department of Health, Education, and Welfare. The two-and-a-half-inch-thick report which stemmed from the four-year study was released in 1963. Director of the project was Professor Harry Levin. Other faculty members, all psychologists, who performed and supervised the research, in which graduate students participated, were Eleanor J. Gibson, Alfred L. Baldwin, James J. Gibson, Charles F. Hockett, Henry N. Riccuiti and George J. Suci.

This is an excellent study. The research attempted was basic and the hypotheses tested were well thought out. The experiments to test the hypotheses were carefully designed and control groups were used to give an accurate measurement of the findings. Several studies were incomplete in their findings. We can only hope that the Cornell researchers or others will continue the work to a definitive conclusion. But the fact remains that the Cornell study was a highly scientific examination of how a child learns to read and, as such, a major contribution to the knowledge of reading and a tribute to Cornell University and its faculty. Unfortunately, copies of the full report are difficult to obtain. There is, however, an excellent evaluation of the findings by Eleanor Gibson in *Science*.[2]

We place great emphasis upon this study because it was obviously predicated upon knowledge of the neurological process of reading. The researchers had an awareness, for example, that reading is translating graphic symbols into sound, and the findings of the well-designed experiments provide the best indication so far of precisely how the child goes about this process. There are thousands of experimental studies which have been done to try to explain normal reading processes. The great majority of these are single isolated studies with little connection to the central problem, less applicability to teaching theory, and almost no neurological information. Many of these studies are poorly conceived and performed with inadequate control. It is neither necessary nor possible for this article to contain

a critical review of this literature. The interested reader may find many excellent references in the Cornell study and may pursue the various subjects involved in the several indices available.

In her *Science* article, Dr. Gibson makes this statement: "Once a child begins his progression from spoken language to written language, there, are, I think, three phases of learning to be considered. They present three different kinds of learning tasks, and they are roughly sequential, though there must be considerable overlapping. These three phases are: learning to differentiate graphic symbols; learning to decode letters to sounds ('map' the letters into sounds); and using progressively higher-order units of structure." The Cornell researchers set up experiments to explore each of these three stages.

Learning to differentiate each printed letter or number used in English is the first step in learning to read and it is not very easy. The same letter comes in various styles, such as capital and lower case, printed and cursive. There are a wide variety of typefaces, including *italic*, and a considerable range of sizes. When the letters are made by hand, as by a teacher, the variations both in printing and handwriting are endless and all of them vary in innumerable ways from printed letters.

Preschool Training

The greatest difficulty for the beginning reader is that his preschool experiences may not have prepared him to discriminate between letters. For one thing, the child must discover the concept that an object (a letter) is not always the same regardless of its position. Nothing in his previous experience has prepared him for this. He knows, for example, that a golf club is a golf club no matter what its position or setting is. It's a golf club in his father's hand on the eighteenth fairway, in the golf bag in the closet, in the sporting goods store, whether new or damaged backward or forward, upside down, horizontal, or wrapped around a tree in his father's frustration. No matter what one does with it, a golf club is always a golf club.

Then, in the sixth year of his life, the child goes to school and is shown something that roughly resembles a golf club—the letter d. Only now he has to understand that if the letter is moved, it becomes a b or a p or a q or, if the handwriting is imprecise, an h or a g—all of which are different things. Similarly, a word is not always the same regardless of its position. Saw, reversed, becomes was. Dog becomes god, cat becomes tac, rat becomes tar, and so on.

A child's preschool training hampers him in learning to read in another and more serious way. He has had relatively little experience with linear objects. He exists, prior to going to school, largely in a three-dimensional world of toys, balls and bats, knives and forks, water glasses, and other objects which have depth and shape he can touch. He has had relatively less experience with two-dimensional linear objects, which is what letters and numbers are. He is simply less accustomed to functioning and conceiving of a linear world.

Even the limited experience he has had in working with linear objects has not particularly prepared him to work with letters. He has colored, painted, and drawn cats and dogs, people, and other figures. With few exceptions, the letters in the English alphabet don't resemble cats and dogs and people. Letters consist of curved and straight lines in various combinations. Even the reading-readiness studies he has in kindergarten are not particularly helpful, for there he usually learns to differentiate between cat and pumpkin faces and other objects. It must be said that the preschool training of children might be more helpful if the child worked more with letter-like forms, rather than drawings of objects. It might help accustom him to the forms of letters that he will be using in learning to read in the first grade.

The initial task to be accomplished in learning to read is differentiating and identifying (not necessarily by name) the letters of the alphabet. This is a basic departure from the manner in which the child learned to speak. Although he differentiated between the sounds of English, he was not required to identify them. He didn't have to know that he was uttering a long a sound or a short e sound or any other, nor that the sound was part of his language. But in reading it is vital that he identify the letters, *even with the look-say method of reading*. He must discriminate at least the first and last letter of the word. When identifying the word cat, he is not required to identify the c and t by name, but he has to know that they are not d and a or other letters. He has to be able to distinguish the shapes of letters and discriminate them from others. In writing letters, the ability to discriminate is even more essential.

Perception

In neurological terms, the child, when he discriminates between letters (or the shapes of any objects), is using visual perception. The term *perception* is given a variety of different meanings by those who use it. The psychologist gives the term a broad meaning, to encompass anything a person becomes aware of in his environment. The dictionary defines perception as anything known of an object; the seeing or hearing of it; direct acquaintance with anything through the senses. Psychologists R. M. Mowbray and T. Ferguson Rodger[3] define *disordered perception* as the inability to organize stimuli in a meaningful fashion. *Stedman's Medical Dictionary* says perception is "the mental process by which the nature of an object is recognized through the association of a memory of its other qualities with the special sense, bringing it to consciousness."[4]

We use perception in a narrower sense—defining it as the ability to be aware of and conceive of a pattern or shape. This is a higher-order sensory function and involves interpretation and integration of the basic information of sight, hearing, touch, etc. In visual perception this is the recognition that a triangle, the end of a tent and a capital A are the same shape; in auditory perception, the recognition of a tune or melody played in a different key; and in touch, the ability to correctly identify by touch alone the textures of velvet and denim. In reading, visual perception means the ability to differentiate between the letters d and b, for example; auditory perception means the ability to differentiate between the sounds of the words leaf and leave.

Two major comments ought to be made about perception. First, it is difficult to know how a child fails to perceive. For example, if a child has a disorder of visual perception and he is asked to draw a triangle and renders it poorly so that it resembles an oval—does he do it because his brain is unaware that a triangle is composed of three straight lines connected by three angles? Or does his brain receive this information but is unaware of its significance, causing him to neglect this information? We don't know the answer.

Second, perception is learned. This has been shown by research with persons blind from birth who have regained their sight through surgery. Psychologist D. O. Hebb has written a fascinating account of this research:[5]

The idea that one has to learn to see a triangle must sound extremely improbable, and so I shall now present the evidence to this effect more systematically. We have seen that the perceptions of the congenitally blind after operation are almost completely lacking in identity. Senden reports cases in which there was an immediate perception of differences in two figures seen together, but also one definite instance in which even this was not possible. Thus the patient sometimes saw differences between a sphere and cube, sometimes not. Color has been found to dominate form persistently in the first vision of these patients. Eleven months after operation the color names learned by a patient in hospital were retained, but the little that had been learned of form was forgotten. An egg, potato, and cube of sugar were seen by a patient repeatedly, until naming was prompt, but then were not recognized when put into colored light; the cube was well named when it was seen on the table or in the investigator's hand but not recognized when suspended by a thread with a change of background.

Such patients, when learning has proceeded far enough, manifest the characteristic generalizations of the normal person, so the initial difficulties are not put down to structural defects of the sensory apparatus.

Riesen has fully confirmed the conclusion that ordinary visual perception in higher mammals presupposes a long learning period. His observations concerning the almost complete visual incapacity of chimpanzees reared in darkness, and the slowness of learning, are of the greatest importance. They show that Senden's similar results with man are not due to some inadequacy of the clinical tests, nor peculiarly human.

Hebb then writes:

The course of perceptual learning in man is gradual, proceeding from a dominance of color, through a period of separate attention to each part of a figure, to a gradually arrived at identification of the whole as a whole: an apparently simultaneous instead of a serial apprehension. A patient was trained to discriminate square from triangle over a period of 13 days, and had learned so little in this time "that he could not report their form without counting corners one after another. . . . And yet it seems that the recognition process was beginning already to be automatic, so that some day the judgment 'square' would be given with simple vision, which would then easily lead to the belief that form was always simultaneously given" [Hebb is quoting Senden]. The shortest time in which a patient approximated to normal perception, even when learning was confined to a small number of objects, seems to have been about a month.

It is possible then that the normal human infant goes through the same

process, and that we are able to see a square as such in a single glance only as the result of complex learning. The notion seems unlikely, because of the utter simplicity of such a perception to the normal adult. But no such argument can be valid, since Lashley has shown that subjective simplicity and immediacy may be very deceptive as an index of physiological simplicity. There are moreover residual traces of learning in normal perception, and hints of its complexity.

Gellerman reports that chimpanzees and two-year-old children recognized a triangle that had been rotated through 120° from the training position, but (in the one protocol that is given) responded selectively only *after* a head rotation; and persistent head rotation continued in the later discriminations. Older human subjects do not need to make the same receptor adjustment to recognize the figure in two positions, and so this generalization may be a learned capacity, simple as it seems to us.

This research into the nature of perceptual learning, which Hebb has summarized so well, is of the greatest importance in the teaching of reading. The distinctive shapes of letters and numbers do not leap into recognition as they do with an adult. The child must examine the figures to detect their distinguishing characteristics. For example, when identifying a square, he actually counts the corners.

This was shown by an experiment related by Hebb,[6] as follows:

The subject is shown a diagram such as

x	e	a	q
r	l	i	s
o	f	z	g
d	y	u	p

and studies it until he has, apparently, an image of the whole square and can "look at" it and read the letters off, one by one. If he really has such an image, it will not matter in what direction he is asked to "read." Actually, it is found that the subject cannot reproduce the letters as fast from right to left as from left to right, or promptly give the four letters, p, z, l, x, that make up the diagonal from lower right to upper left. So what seems a simple, immediately given image of the whole is actually a serial reconstruction of parts of the figure. An "image" of triangle or square is simpler, longer practiced, but may be fundamentally the same. The perception of such figures also may involve a temporal sequence.

Thus, the normal child must *learn* to discriminate the shapes of letters, whether he is being taught by a phonic or a look-say method.

Identifying Letters

At this point it is proper to consider the difficulty which the normal child has in identifying letters. The Cornell study sought to discover how a child differentiates one letter from another.

It was obvious to the Cornell scientists that letters of the alphabet could not be used to discover how the child learns them. The children being tested might know one or several letters. They would at least have a familiarity with them. To avoid this difficulty, the researchers prepared a group of letter-like forms consisting of straight and curved lines such as those used in letters. Then, 12 variants were prepared of each standard letter-like form. In some of the variants the forms were rotated or reversed (as letters are); or curved lines were used instead of straight ones; or there were breaks in the lines that did not exist in the standard form; or there were perspective transformations in which the standard figure was slanted backward or forward.

Then the Cornell psychologists asked a group of children, ages four through eight, to pick out copies of the standard form from a group that included all of its transformations. The youngsters were to select only the exact copies of the standard form. The errors made by the children were scored and the errors classified according to the type of transformation.

Results of the test showed that the visual discrimination of children improved from ages four to eight, but that some discriminations between forms were harder to make than others and that improvement in discrimination varies from form to form. For example, errors for perspective transformations were very numerous among four-year-olds and still numerous among eight-year-olds. This was not considered critical because English letters do not normally contain perspectives, that is, the letters are all made to appear flat. At least in the primary grades, there is no attempt to give the letters the appearance of depth.

Of greater significance were these results: changes of break or close, such as between a c and an o, are easiest for children. Even the youngest tested made relatively few errors and none of the eight-year-olds made a mistake.

Errors for rotations and reversals—d and b, p and q, M and W, c and u—were very high among the four-year-olds, but dropped to nearly zero by age eight.

Errors for changes from line to curve—v and u, for example—were relatively numerous (depending on the number of changes) among the youngest children but showed a rapid drop among the older ones, almost to zero for the eight-year-olds.

The Cornell researchers then tried the same transformations of real letters on the five-year-old group and found that the same confusions resulted. This indicated that problems in discrimination apply generally and not just to the specific forms drawn for the experiment.

Some comments can be made concerning the results of this experiment. First, a child's ability to distinguish one letter from another improves with age. By age eight he is an expert, making hardly any mistakes at all. But the child of eight is usually in the third grade. What of the first-grader who is having trouble discriminating one letter from another? Is he receiving proper help from his teacher? Teachers work quite hard on reversals and rotations, but do they realize that line-to-curve distinctions also cause difficulty? The answer to these questions is somewhat important, for the Cornell study showed that at age six the children tested made about 18% errors in rotation and reversal and 26% in line-to-curve transformations.

How does a child differentiate one letter from another? If the answer to this question could be obtained, it would open a new avenue of teaching, in which instruction can be given to the child to help him distinguish one letter from another, thus eliminating some of the time-consuming trial and error of self-discovery.*

*The use—he would say abuse—of self-discovery learning in reading instruction has been criticized by psychologist Roger Brown in an article "A Dispute about Reading" in the book *Human Learning in the School*,[7] as follows:

"The need for phonetic attack on new words is generally recognized by educators of the look-and-say persuasion, but for one reason or another they believe the necessary generalizations should be incidentally learned or, if directly taught, postponed until the second or third grade. What are the reasons for this belief? Dolch and Bloomster have said: 'It is true that the use of phonetics means the use of generalizations, *that generalizations are best learned inductively*, and that sight words are the basis of inductive reason-

The Cornell experimenters formed two hypotheses concerning how children might discriminate letters. In one it was assumed that the child builds up a kind of model of each letter and then compares until he makes a match, or, in the other, that he discovers how letters differ and recognizes them by distinctive features.

To test which hypothesis was correct, the psychologists worked with a group of kindergarten children, training them to discriminate between letter-like forms similar to those used in the earlier experiment. Then the children were divided into three groups. Group one was given new forms to learn, forms which varied in new ways from the same standards of discrimination they had already learned. Group two was given new sets of forms which differed in the same ways as the forms they had already learned. The third group was a control given both new standards and new dimensions of difference to discriminate.

It was inferred that better performance by the first group would suggest that discrimination learning proceeded by construction of a model of the standards against which the variants could be matched. If the second group performed better it would suggest that distinctive differences had been detected by the children.

ing.' (Italics my own.) The italicized portion of this sentence is hardly a common-sense observation. Why does the scientist write out his laws, the chef his recipes, the professional golfer his instructions for the novice, if not to spare the rest of us inductive labor? We benefit from the experiences of our predecessors by reading the generalizations reformed. It may be that the Darwinian Theory of Evolution is best learned inductively—best in the sense of most unforgettably. But if it had to be learned that way, most of us would live without a theory of evolution. On the face of it, a generalization is more rapidly and certainly learned when it is explicitly stated. In addition, there are experimental results to show that incidental learning is slow and uncertain by comparison with directed learning. The educator, who would claim that phonetic generalizations are better learned by incidental induction than by direct formulation with examples, assumes the burden of proof. His claim does not conform to popular belief, nor has it been demonstrated in the laboratory. If you really want your pupil to learn a phonetic rule, it seems sensible to tell him the rule."

Results showed that both groups one and two performed better than the control group, and that group two performed best, making 39 errors to group one's 69. "We infer from these results," Dr. Eleanor Gibson wrote in *Science*, "that, while children probably do learn prototypes of letter shapes, the prototypes themselves are not the original basis for differentiation. The most relevant kind of training for discrimination is practice which provides experience with the characteristic differences that distinguish the set of items. Features which are actually distinctive for letters could be emphasized by presenting letters in contrast pairs."[8]

The experimenters made an effort, unfortunately not completed, to determine which features a child distinguishes. It seemed to indicate that children distinguish between curved and straight lines and between the obliqueness of a line, as in A, K, N, and Z. It is to be hoped these experiments can be continued until it is known precisely which features of letters help a child distinguish it from another.*

The Cornell study seems to indicate that a teacher would be wise to drill students on discriminating between letters as well as identifying them.

*We would like to suggest that some experimenters develop what might be called an *Initial Perceptual Alphabet* (IPA), a concept similar to the *Initial Teaching Alphabet* (ITA). ITA is an attempt to circumvent the phonetic irregularities of the English alphabet by creating letter figures for each of the common phonetic elements in the language, 44 in all, so that each ITA letter represents one English sound. After learning by this method, the child later transfers easily to a regular alphabet. We consider this a most appealing addition to the theory of reading instruction. We are suggesting that a similar technique be used to circumvent some of the visual confusions in the alphabet, such as the b and d, p and q, m and w, u and v. If another form were substituted for one of the confusing letters—there is no reason that squares, triangles and other geometric forms cannot be used—it would simplify the visual aspect. The child, after benefiting from his IPA exposure, could then be transferred to the regular letter forms.

Reading and Writing are Related

Another team of psychologists at Cornell sought to determine the correlation between reading and writing. The hypothesis was stated well by the researchers, James J. Gibson and Harry Osser:

> In the acquisition of language it is clear that a child never learns to understand speech without at the same time learning to speak. The circularity of speaking and hearing has always been recognized and the degree to which the auditory feedback controls the process of uttering words has recently been studied experimentally. What has not been so clear is that a child never learns to *read* without at the same time learning to *write*. Reading and writing are different terms and often seem to be thought of as different school subjects. Nevertheless, the visual feedback which controls the manual art of writing is quite analogous to the auditory feedback which controls the vocal art of speaking. Just as one cannot speak without hearing one's speech, so one cannot write without, in a peculiar sense, reading one's writing.

Gibson and Osser pointed out that what a child must learn in order to read and write is that "speech sounds can appear, and can be *made* to appear on a visible surface."

Is it useful in the classroom to have the child write letters as a means of helping him to discriminate and identify them? Gibson and Osser sought to discover this by having 20 children, four to six years of age, punch out letters on a typewriter. Some of the children used a typewriter that contained a ribbon, thus permitting them to see the letters they made. The remainder used typewriters without ribbons and thus received no visual reinforcement of their efforts.

Results showed that those children who used typewriters with ribbons performed significantly better than those who merely punched a typewriter key. The results are interesting in that they showed that merely by looking at letters the child made with a typewriter helped his discrimination of them. It is unfortunate, however, that typewriters were used in this experiment. If another group of children had written or printed the letters by hand, it is likely that they would have shown even greater reinforcement of their ability to discriminate. There is abundant evidence that tactile perception provides an avenue of learning. Helen Keller used this method exclusively. Schools experimenting with the teaching of dyslexic children with severe visual and auditory imperception are

obtaining good results by teaching children to read by means of tactile perception, that is, having them feel letters and write them in sandboxes or on blackboards. (Grace Fernald[9] has done the most significant investigation of the efficacy of tactile methods of teaching reading.)

We believe there is great value in teaching reading and writing simultaneously, rather than as separate subjects in the curriculum. Writing the letters aids the child in distinguishing and identifying them. He is using visual perception when he sees the letters, auditory perception when the teacher speaks them, and tactile perception when he writes them on paper or the blackboard. The normal child thus is using three broad avenues to language comprehension. This three-pronged learning process is of value even after he has learned the first step in reading and can distinguish and identify letters. Writing, as well as seeing and hearing, help him to learn the spelling patterns and then the sentence structures which are characteristic of English. In short, writing is a most valuable tool in the teaching of reading.

Identifying Words

The importance of teaching children to discriminate one letter from another very early in the instructional program was illustrated in another Cornell experiment. Performed by Gabrielle Edelman, this investigation produced results which have far-reaching significance for the practicing classroom teacher.

Miss Edleman sought to discover the cues by which a nonreader or beginning reader identifies a word he has never seen, whether the same cues are used to recognize a long word and a short word, whether nonreaders and beginning readers use the same cues, and whether boys and girls use the same cues. Two groups were selected; 50 kindergarteners and 50 first-graders, each chosen at random from public schools and each divided equally among boys and girls.

The children were shown a card on which was printed a nonsense word, for example, cug. Then the youngsters were shown response cards in random arrangement. They were to point to the word on one of the response cards which was identical or most resembled the word they had seen on the first card. The response cards were arranged so as to determine (1) whether the children cued on the basis of shape by selecting arp, which has the same shape as cug but all the letters changed; (2) by the first letter by selecting che, which has the same first letter as cug but different second and third letters and the shape changed; (3) on the basis of the second letter by selecting tuk, which has the same second letter as cug but the first and third letters and the shape are different; or (4) on the basis of the final letter by selecting ilg, which has the same third letter but the first two and the shape are changed. A similar system was worked out for five-letter nonsense words. In both the three-letter and the five-letter tests, the response cards were presented in varying order so no cue could be based on sequence. There were eight combinations of each three-letter word and 52 combinations of each five-letter word.

The results were different depending on the size of the word and, surprisingly, on the sex of the participants. The first letter of both the long- and short-word forms was the cue most utilized by nonreaders (kindergarteners) and beginning readers (first-graders). The last letter is also an important cue, especially for kindergarteners, and more so in short words than in long ones. Boys tend to recognize words on the basis of the first more than the last letter. Girls, while using both first and last, place greater emphasis on the second letter than boys do, as shown by the following table:

Five-Letter Words

Cues:	SHAPE	FIRST	SECOND	THIRD	FOURTH	FIFTH
Kindergarten	330	1673	540	755	518	1365
1st Grade	80	2497	757	693	287	930
Boys	214	1886	589	780	445	1208
Girls	196	2284	708	614	360	1087

(*The figures represent the number of times children recognized words on the basis of certain cues.*)

Gabrielle Edelman concluded from her experiment that "theories which propose that nonreaders and/or beginning readers recognize words as wholes by their shape have not been supported in this study. The shapes of words, offered as a cue next to letter cues, was rejected in favor of letter cues . . . in this experiment." She pointed out that the first letter is the most important cue in whole-word recognition

and that the last letter is next in importance. She theorized that this phenomenon may lie in the primacy of the first letter and the recency of the last, or simply that the first and last letters, since they are bordered on one side by white space, stand out more than those letters embedded in the middle of a word.

> The major implication for the teaching of reading [according to Miss Edelman, a view which we share] is that the basic belief on which the whole-word method of teaching reading lies (i.e., the belief that children recognize words by their shape) is incorrect. Educators may believe the child is attending to the whole word, when he is actually utilizing certain letter cues. Helping pupils learn the letters well so that they may use letter cues to the best of their ability would be an important teaching improvement.

This information about the manner in which a normal child recognizes and identifies the graphic symbols on a page is of the greatest possible importance in teaching of reading. It offers, we believe, some insights into the problems of the normal child in learning to read and to some ways teachers can assist this child over these hurdles.

But our primary purpose in including this material is to show the monstrous task that confronts the dyslexic child with poor visual perception. If he does not correctly perceive the shape of the letter d, for example, just try to imagine his difficulty in differentiating the letter from a b, p or q. If he does not correctly perceive the shape of an m, how can he distinguish it from a w? And making such distinctions is the absolutely essential first step in reading. This child, even if his impairment is a mild one, needs a great deal of time-consuming help in surmounting the first step in reading.

This article is a reprint of chapter 5 in R. M. N. Crosby (with Robert A. Liston), *The Waysiders: a New Approach to Reading and the Dyslexic Reader.* New York: Delacorte Press, 1968.

1. The Cornell University study, *A Basic Research Program on Reading*, consists of 22 separate papers which are not sequentially numbered, so that page references would be of little significance. Because copies of the full report are difficult to obtain, additional references will be listed for each paper, if published elsewhere. The papers discussed in this chapter are:

Gibson, Eleanor J.; Gibson, James J.; Pick, Anne D.; and Osser, Harry. "A Developmental Study of the Discrimination of Letter-Like Forms" (also published in *J. Comp. Physiol. Psychol.*, 55:897–905, 1962).

Gibson, Eleanor J., Osser, Harry, Schiff, William, and Smith, Jesse. "An Analysis of Critical Features of Letters, Tested by a Confusion Matrix."

Pick, Anne D. "Improvement in Visual Discrimination of Letter-Like Forms" (also published in *J. Exp. Psychol.*, 69:331, 1965). Gibson, James J., and Osser, Harry. "A Possible Effect of Learning to Write on Learning to Read."

Edelman, Gabrielle. "The Use of Cues in Word Recognition."

2. Gibson, Eleanor J. "Learning to Read," in *Science*, 148 (May 21, 1965), 1066–1072.

3. Mowbray, R. M., and Rodger, T. Ferguson. *Psychology in Relation to Medicine.* Edinburgh: E. and S. Livingstone, 1963, p. 208.

4. *Stedman's Medical Dictionary.* Baltimore: William and Wilkens Co., 20th edition, 1961.

5. Hebb, D. O. *The Organization of Behavior.* New York: John Wiley and Sons, 1949, pp. 31–33.

6. *Ibid.*, p. 36.

7. Brown, Roger. "A Dispute About Reading," in *Human Learning in the School*, John P. DeCecco, ed., New York: Holt, Rinehart and Winston, 1964, p. 348. (Reprinted from Brown, Roger: *Words and Things.* Glencoe, Illinois: The Free Press, 1959, p. 73.)

8. Gibson, Eleanor J., p. 1068.

9. Fernald, Grace. *Remedial Techniques in Basic School Subjects.* New York: McGraw-Hill, 1943.

Relative Legibility of Leroy and Lincoln/MITRE Fonts on Television

Donald Shurtleff

The legibility of standard Leroy alphanumeric symbols was compared with that of a new font, the Lincoln/MITRE, on a television monitor at resolutions of 8, 10, 12, and 14 lines per symbol height. The new font was not superior in legibility to the Leroy font at any of the values of resolutions tested. While the findings for the new font were negative, insights were gained about how to improve symbol design for more legible television displays. It was recommended that these new design techniques be evaluated in future work on television displays.

Television is a valuable display device for systems use because of its versatility, ease of signal transmission, reliability of image reproduction, ease of maintenance, and comparatively low cost. In addition, the ability of television to combine different data inputs into a single composite display is well known. Nevertheless, the acceptability of television for many military and industrial systems applications depends upon its ability to display symbols which can be accurately and quickly identified by the viewer.

This ability has seldom been determined through objective performance tests that provide estimates of accuracy and speed (legibility) of symbol identification. Even though television is widely used for entertainment, education, and communication, the research which might have solved some of the legibility problems has been directed elsewhere instead. Commercial TV studies lean to such problems as picture quality, flicker, color quality, and in educational TV, to evaluations of television as an instructional device. When television is used as a means of communication in system settings, symbol legibility is often determined by subjective opinions, preferences, or even guesses.

There is a need to conduct comparative studies of different fonts for developing standards to guide the designer and manufacturer of display equipment to select the most legible symbols. The present study tried to select a better font for television use by studying the relative legibility of standard Leroy symbols and a set of improved symbols (Lincoln/MITRE) on a television monitor. An improved symbol font may be expected to aid television legibility in either one of two ways (or both) by lowering the minimum number of scan lines per symbol height required for a high accuracy of identification, or to produce faster identification times at previously established minimal values of symbol resolution (10 to 12 lines per symbol height, see references 2, 3, 8, and 9).

A set of alphanumerics which might best serve as a standard would retain good legibility when displayed on any display such as a shaped-beam or slewed-beam cathode ray tube, a high speed printer, an office typewriter, a television monitor, and so on. Work on the development of a universally legible font was started several years ago and, in part, continued some earlier work at Lincoln Laboratory. Essentially, this work involved refining a set of symbols originally designed by Mackworth. The history of the development of this font is described in more detail elsewhere.[5]

The latest version of this font called Lincoln/MITRE (L/M) is shown in Figure 1. In a recent study[4] the L/M font was compared with the Leroy font (Fig. 1) which is a standard lettering style used extensively in commercial art and advertising. The results of the study showed that subjects made fewer errors identifying tachistoscopically presented L/M symbols than identifying Leroy symbols at each of several values of brightness contrast ratios, ranging from 4:1 to 10:1.

While the work to date with the L/M font is encouraging, there is a need to conduct additional evaluations of this font before it may be recommended as a standard for use in other display applications. Furthermore, the tachistoscope study indicated that some additional improvements might be made in the legibility of L/M symbols by changes in the geometry of those symbols which the subjects misidentified most frequently. However, before any additional changes in symbol design were made, it seemed desirable to collect more data on inter-symbol confusions when the L/M font is tested in other kinds of displays.

Since the legibility of televised symbols has been a major and con-

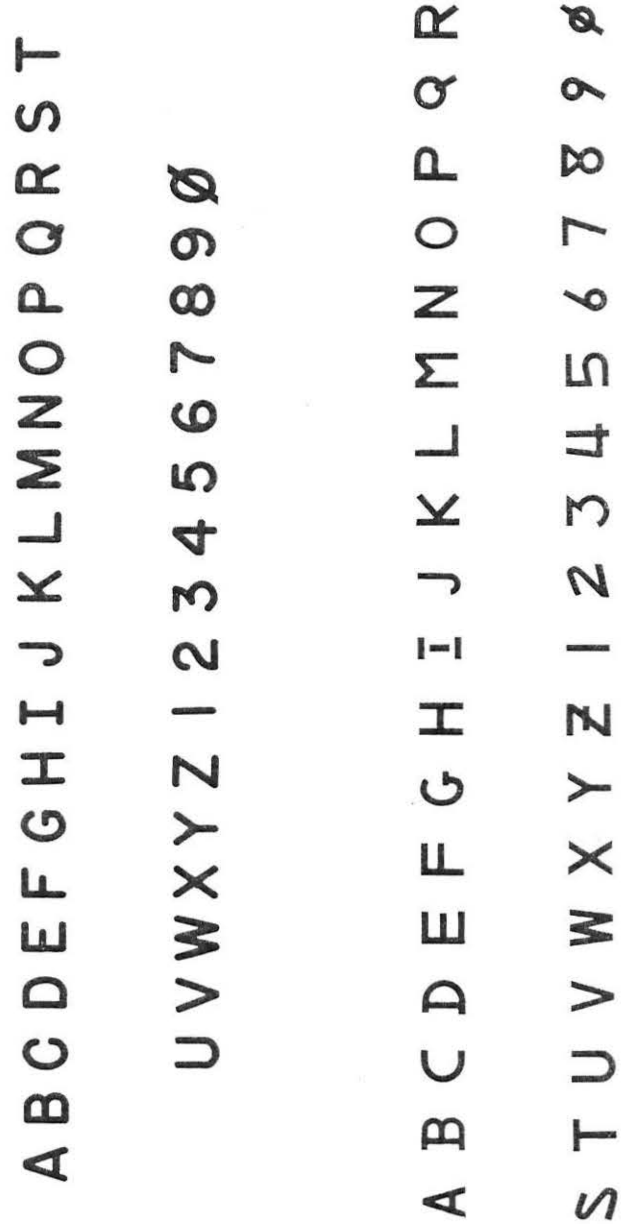


Figure 1. Leroy font (top) and Lincoln/MITRE font.

tinuing interest at MITRE, it seemed reasonable to extend the evaluation of the L/M font by comparing it with the Leroy font on a television monitor. Television represents a unique problem in symbol design because of the way in which the symbols are constructed and displayed. There are two major characteristics of television which influence symbol geometry; the cutting up of symbols by the active lines of the television raster, and the "on-off" characteristics of the scanning element. The first characteristic affects symbol geometry by deleting selected parts of the symbol, while the second characteristic may affect symbol geometry by smearing, which is caused by the lack of a sharp "on—off" response of the scanning element in horizontal transitions from light to dark areas. Both of these characteristics, the cutting up and the smearing of symbols, are shown clearly in Figure 2 where photographs of selected televised symbols at 10 lines are presented.

Previous attempts to develop a font uniquely suited to television have failed.[7,8] In each case, the improved font was no better than standard Leroy symbols. In the present study, the Leroy font was compared with the L/M font at symbol resolutions of 8, 10, 12, and 14 lines per symbol height. The results showed no marked superiority of L/M symbols over Leroy symbols at any of the resolutions studied. As in previous studies[2,3,8,9] legibility for both fonts was greatly impaired for resolutions below 10 lines per symbol height. While the findings for the L/M symbols were disappointing, the results provided some new insights into other, and hopefully more fruitful techniques for improving the design of symbols for television displays.

Methods

The subjects were four MITRE employees who had 20/20 near and far acuity, normal color vision, and no marked phoria.

Television Equipment. The television equipment and manner of presenting symbols to each subject is described in detail in a previous report[1] and only a brief description is given here. The symbols were projected onto a translucent screen which was mounted on a modified Motion Analyzer. The symbols were picked up by a 945-line General Precision camera (Model 820) and shown to the subject on a Conrac (Model CQE 14/945) 14 inch video monitor. The camera-to-screen

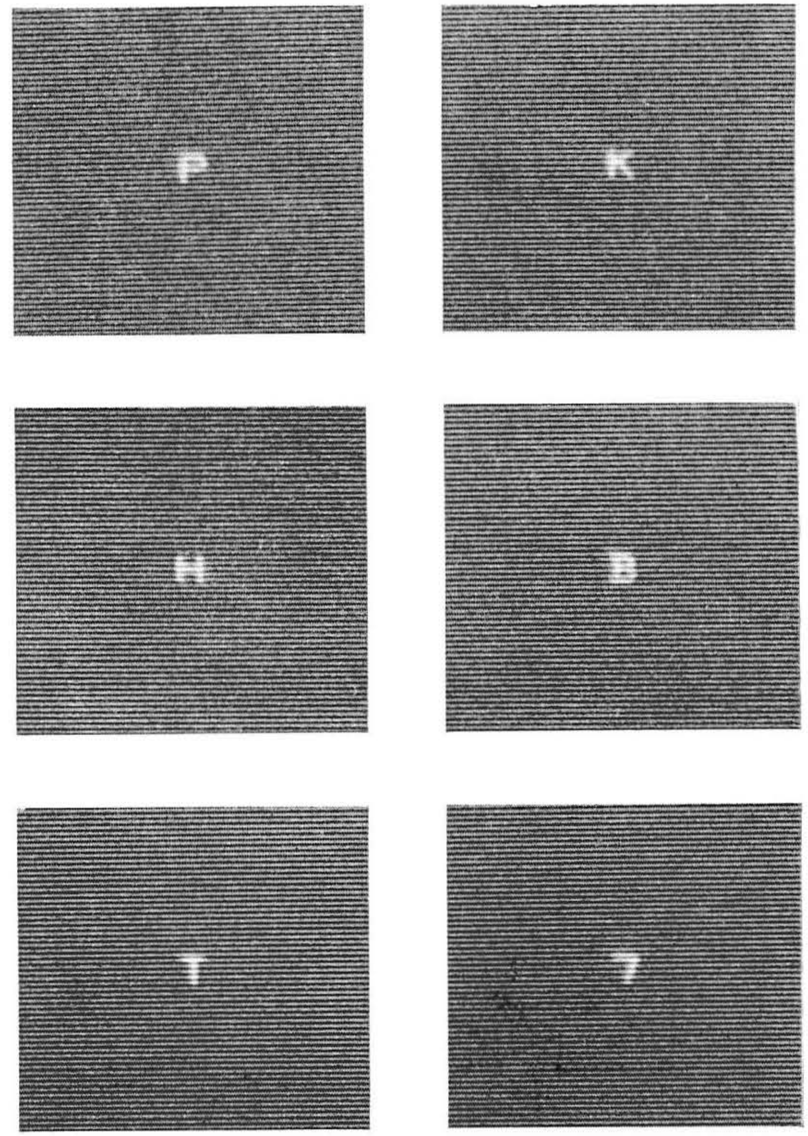


Figure 2. Symbols resolved by ten scan lines.

distance was arranged to obtain the desired line resolution, and the subject-to-monitor distance was arranged to maintain an angle of subtense at the eye of 16 minutes of arc. The subject initiated the exposure of a symbol by depressing a button. The exposure of the symbol was ended when the subject made his verbal identification. The subject was instructed to make his identifications as quickly and accurately as possible. The time required to identify each symbol, and the symbol named, were recorded.

The L/M and Leroy Symbols. The symbols were photographed on 35mm. film strips. Each strip contained 180 symbols of a given font with the 36 symbols appearing five times each. The average symbol width for the two fonts was three-quarters of the symbol height. The two fonts had a ratio of stroke-width to height of one-sixth. It was necessary to modify the standard Leroy Ø and I in order to differentiate the Ø from the letter O, and the numeral 1 from the letter I.

The sequence of symbols on the film strip was determined by a table of random numbers. A stepping switch controlled the advance of the film through the film projector and provided a number of different symbol sequences, which helped to prevent the subjects from memorizing the letter sequences.

Experimental Design. Each subject identified symbols in both fonts at each of the four values of resolution (8, 10, 12, and 14 lines). The subjects viewed one font at all resolutions before being presented the other font, two of the subjects seeing Leroy first and the other two seeing Lincoln/MITRE first. The two subjects seeing Leroy first were presented the resolutions in two different orders which were determined by a table of random numbers. These same sequences of resolutions were used also for the two remaining subjects who started with the L/M font. When the subjects were switched to the alternate font, two new orders of resolutions were made up with a table of random numbers. Each subject seeing the Leroy font viewed one of the new sequences and these same sequences were used for the two subjects who saw the L/M font.

Each of the subjects made a total of 180 symbol identifications (five per symbol) for each font at each of the four resolutions. Before each series of sessions with a given font, the subjects were given practice in identifying the symbols making up that font. The practice session

included 180 identifications, five for each symbol of the font. These symbols were shown on the television monitor and were resolved by 60 active lines per symbol height. During practice any errors made by the subject were corrected by the experimenter and errors rarely occurred during practice.

Characteristics of Televised Symbols. The active lines in the symbols had an average brightness of approximately 20 fL and a background brightness (to one side of the symbol) of approximately 2 fL as measured by a Spectra Brightness Spot Meter. The procedure followed in adjusting the television equipment before each experimental session is described by Bell.[1]

Results and Discussion

The percentage of identification errors for L/M and Leroy symbols at each of four values of resolution are shown in Figure 3; the identification speed for these two fonts at the same values of resolution are shown in Figure 4. As Figures 3 and 4 indicate, there were no marked differences between the two fonts in either accuracy or speed for any of the resolutions studied. The speed and accuracy of symbol identification for each subject are presented in Tables I and II. From Tables I and II it is evident that none of the differences between fonts were very large and statistical analysis revealed no significant differences in these data. Even the relatively large mean differences in identification time for the two fonts at a resolution of eight lines was not statistically significant.

The effects of decreases in resolution on speed and accuracy of symbol identification for both fonts is similar to that reported in many previous studies.[2,3,8,9]

Two conclusions follow from these (1) data: Televised L/M symbols are not superior in legibility to televised Leroy symbols, and (2) a minimum resolution of 10 lines per symbol height is required for a 90% or better accuracy of indentification.

Inter-symbol Confusions. The particular symbols which had the highest concentration of errors were similar for the two fonts at resolutions of 8 and 10 lines. The only notable difference between the two fonts was at a resolution of 12 lines where there was no confusion among the

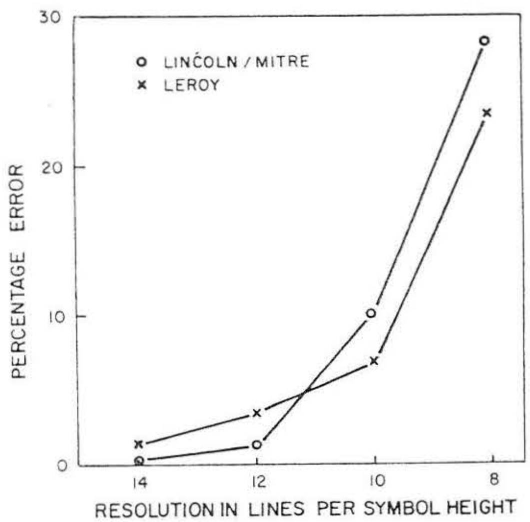


Figure 3. Percentage error for L/M and Leroy symbols.

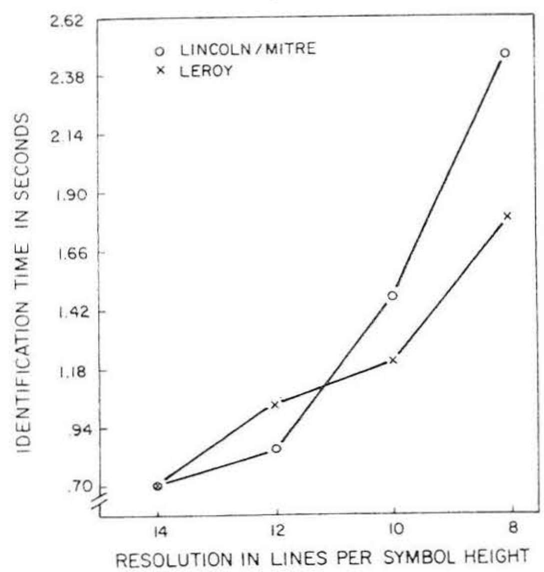


Figure 4. Identification time for L/M and Leroy symbols.

TABLE I. *Percentage Error for Each of Four Subjects*

Resolution in Lines Per Symbol Height

Subjects	14		12		10		8	
	L/M	Leroy	L/M	Leroy	L/M	Leroy	L/M	Leroy
1	0	1	0	6	2	7	8	14
2	1	3	2	2	8	9	36	42
3	0	0	3	3	12	5	23	17
4	0	1	0	3	18	7	46	22
Mean	0.25	1.25	1.25	3.50	10.00	7.00	28.25	23.75

TABLE II. *Identification Time in Seconds for Each of Four Subjects*

Resolution in Lines Per Symbol Height

Subjects	14		12		10		8	
	L/M	Leroy	L/M	Leroy	L/M	Leroy	L/M	Leroy
1	0.65	0.69	0.76	1.49	1.01	1.32	2.93	1.41
2	0.63	0.69	0.75	0.71	1.08	0.90	1.38	1.50
3	0.54	0.57	0.87	0.71	1.42	0.82	1.63	1.36
4	0.96	0.84	1.04	1.25	2.36	1.75	3.92	2.93
Mean	0.70	0.70	0.86	1.04	1.47	1.20	2.46	1.80

L/M symbols while the B, 8, Q, O, G, and 6 of the Leroy font continue to be major sources of error. The absence of errors for the L/M font and the presence of errors for the Leroy font at 12 lines is not too surprising when it is recalled that the L/M font is essentially a refinement of the geometry of a font much like the Leroy.[5] It is noted that by comparing the two fonts (see Figure 1) the geometric refinements include such things as increasing the size of small symbol detail (for example, increasing the length and changing the position of the horizontal bar of the letter G), changing the outline of symbols (for example, changing the upper part of the numeral 8 from a circle to a triangle), and altering the curvature of symbol strokes (for example, changing the curvature of the letter S). The failure of these design changes to aid identification at the lower resolutions is probably related to the fact that small differences in detail and stroke curvature are not resolved sufficiently by the coarse scan structure of the television. Apparently, a scan structure as fine as 12 lines per symbol height is needed before these geometric differences are resolved sufficiently for the subject to be able to detect them and use them in his identifications.

Design of Symbols for Television

It is clear from the results of the present study and previous studies[7,8] that small changes in detail and curvature of strokes of symbols are not going to improve the legibility of television displays. It appears that two other ways of changing symbols should be evaluated before the search for a better television font is abandoned.

In an earlier study[7] twelve Leroy symbols were revised and tested for legibility on a television monitor. Eleven of these revisions involved small changes in symbol detail, but one revision involved a rather simple design change, that of increasing the width of the letter H from 75% to 100% of the symbol height. Most of the changes in small detail were not successful, but increasing the width of the H eliminated both the H-called-M and the H-called-N confusions which previously had been major sources of error. The finding suggests that increasing symbol width might be successful with other symbols involved in major confusions on television.

In addition to increasing symbol width, design changes involving a decrease in symbol stroke-width may be successful. Gross changes in symbol design such as increasing the width or decreasing the stroke-width of symbols may be expected to aid television legibility because the discrimination of gross detail is less dependent upon the fineness of the scan structure than is discrimination of small symbol detail. Furthermore, increasing the width or decreasing the stroke-width of symbols may be expected to improve legibility by reducing the amount of horizontal smearing of symbol strokes. Therefore, further work may produce better symbols for television by studying the effects of symbol width and stroke-width.

1. G. Bell, Studies in Display Symbol Legibility: XVI. The Legibility of Teletypewriter Symbols on Television. The MITRE Corp., Bedford, Massachusetts, ESD-TR-67-104, April 1967.

2. G. Kosmider, Studies of Display Symbol Legibility: V. The Effect of Television Transmission on the Legibility of Common, Five-letter Words. The MITRE Corp., Bedford, Massachusetts, ESD-TR-65-135, May 1966.

3. G. Kosmider, M. Young, and G. C. Kinney, Studies of Display Symbol Legibility: VIII. Further Study of the Legibility of Common, Five-letter Words on a TV Monitor. The MITRE Corp., Bedford Massachusetts, ESD-TR-65-385, May 1966.

4. D. J. Showman, Studies in Display Symbol Legibility: X. The Relative Legibility of Leroy and Lincoln/MITRE Alphanumeric Symbols. The MITRE Corp., Bedford, Massachusetts, ESD-TR-66-115, August 1966.

5. D. Shurtleff, Design Problems in Visual Displays: I. Classical Factors in The Legibility of Numerals and Capital Letters. The MITRE Corp., Bedford, Mass., ESD-TR-66-62, June 1966.

6. D. A. Shurtleff, Design Problems in Visual Displays: II. Factors in the Legibility of Televised Displays. The MITRE Corp., Bedford, Massachusetts, ESD-TR-66-299, August 1966.

7. D. Shurtleff, M. Marsetta, and D. Showman, Studies of Display Symbol Legibility: IX. The Effects of Resolution, Visual Size and Viewing Angle on the Legibility of Televised Leroy Alphanumeric Symbols. The MITRE Corp., Bedford, Massachusetts, ESD-TR-65-411, May 1966.

8. D. Shurtleff, and D. Owen, Studies of Display Symbol Legibility: VI. A Comparison of the Legibility of Televised Leroy and Courtney Symbols. The MITRE Corp., Bedford, Massachusetts, ESD-TR-65-136, May 1966.

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Additional Studies of Television Legibility

1. Botha, B., and Shurtleff, D., Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width, ESD-TDR-63-249, July 1963.

2. Botha, B., and Shurtleff, D., Studies of Display Symbol Legibility: II. The Effects of the Ratio of Widths of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction, The MITRE Corporation, Bedford, Mass., ESD-TDR-63-440, September 1963.

3. Shurtleff, D., Botha, B., and Young, M., Studies of Display Symbol Legibility: III. The Effects of Line Scan Orientation, The MITRE Corporation, Bedford, Mass., ESD-TR-65-138, May 1966.

4. Kinney, G. C., Marsetta, M., and Showman, D. J., Studies in Display Symbol Legibility: XII. The Legibility of Alphanumeric Symbols for Digitalized Television, The MITRE Corporation, Bedford, Mass., ESD-TR-66-117, August 1966.
5. Shurtleff, D., and Marsetta, M., Studies in Display Symbol Legibility: XIV. The Legibility of Military Map Symbols on Television, The MITRE Corporation, Bedford, Mass., ESD-TR-66-315, September 1966.

The above papers may be obtained from: Clearinghouse for Federal, Scientific, and Technical Information, Springfield, Virginia 22151

Typographic Education

This department is an international forum for faculty members, students, practicing designers, and other interested persons who are invited to submit succinct articles dealing with educational trends, fields of study, design techniques, and student problems in the various typographic educational programs.

England: The Working Party on Typographic Teaching

1 *The Working Party*

1.1 *Origins.* The Working Party on Typographic Teaching was set up in October, 1966, by the Society of Industrial Artists and Designers (London), with the active support of the Society of Typographic Designers, in response to repeated criticism from assessors, teachers, and spokesmen from industry that much graphic design work in colleges of art and design was let down by an immature approach to typography. Since then, the Working Party has become an independent and permanent body with nearly fifty active members drawn from departments of printing, colleges of art and design, universities, and a number of branches of industry. Amongst them are representatives of leading national and international organizations and societies connected with typography and graphic design, heads of graphic design and printing departments, and teachers (both full- and part-time) from many parts of the country.

1.2 *Terms of reference.* The initial terms of reference were to consider the place of typographic design in graphic design courses and to suggest means of improving the quality of the teaching of the subject. As work progressed it soon became obvious that the traditional meaning of typography (printing) would have to be extended to include all visual communication systems involving the use of words, numbers, and other symbols. It also became clear that we were really concerned with the fundamental issues of the design process which, in our experience, can best be approached through the study of an industrial design discipline such as typography—engineering or architecture would serve equally well, but typography is the obvious choice in graphic design courses.

1.3 *Regular activities*. The organized activities of the Working Party are of two main kinds: regular monthly meetings for members, and a series of national study conferences. The monthly meetings usually take the form of demonstrations and descriptions of projects which members have undertaken with their own students; and these have provided valuable points of departure for the discussion of general ideas about what we want our students to learn and the value of the teaching methods we use. Other meetings have been conducted as discussions introduced by a member of the group or by a visitor. Among the topics covered have been the teaching of engineering design, courses for teachers of typography and graphic design, and the place of the study of the history of typography, technology, and design. In addition, the Working Party has set up special study groups to consider in more detail a number of such aspects of the teaching of typography.

1.4 *National Conferences*. Three national study conferences have been held. The response to these has confirmed our belief that the dissatisfaction with the present structure of courses and the approach to the teaching of typography and graphic design is widespread. Over 300 people attended the first conference, "Creative teaching in graphic design," which was held in London in October, 1967, amongst them practicing designers, teachers of typography, principals of colleges of art and design, representatives from the printing and allied industries and professional bodies connected with printing, and an observer from the Department of Education and Science.

1.5 *Aims and intentions*. These organized activities have gone some way towards making the aims of the Working Party known, but perhaps its most valuable contribution to date has been in providing an opportunity for the informal exchange of views amongst members with a wide range of professional and industrial experience. Contacts of this kind have enabled us to clarify our ideas and learn from one another; in this respect a particularly important role has been played by those members working in industry.

One of the original intentions of the Working Party was to produce some kind of document outlining basic requirements in relation to courses, staffing, equipment, and so forth. It soon became clear, however, that such a document would be premature, and possibly

even undesirable. In the first place, we have begun to explore new approaches to one area of design education; too specific proposals at this stage might even have the effect of inhibiting further essential experiments. What is clear is that we need a situation that positively encourages new and varied kinds of courses to emerge. Secondly, we believe that courses should be designed to suit the genuine educational needs of students for the benefit of society as a whole, and that they must be shaped to some extent by the interests of particular teachers and by local considerations both inside and outside the teaching centers.

A few examples may help to illustrate this last point. Some study of cybernetics, linguistics, and perception seems to be essential to an ideal course in typography and graphic design, but we do not suggest that these subjects should be obligatory at this stage in view of the difficulty of re-training existing teachers and finding suitable new staff. The history of printing may be most profitably studied, particularly where original material exists locally in a good library, but the history of technology may prove quite as rewarding when studied in an area where interest can be aroused and nurtured by contact with actual examples of engineering from the past. Practical involvement with modern printing machinery may be a most valuable part of a student's course, but it is not absolutely essential, and the nature of the contact would certainly depend on the size and type of the educational institution and the attitude of local industry.

1.6 *The major issue*. This report is therefore mainly concerned with general ideas and principles. Though it has been prepared by members with wide experience of the organization of courses in typography and graphic design, it dwells primarily on the need for a new approach to design education and, as an example of this, the relation of typography to other subjects. The design and implementation of courses must stem from an acceptance of these fundamental propositions.

2 *The Art and Design Conflict*

2.1 *Foundations of design and design teaching*. In our examination of objectives and teaching methods we have found that inadequacies in typographic design teaching mostly stem from the treatment of the subject as a form of personal visual expression, a concern which may be perfectly legitimate in painting and sculpture, but is a distortion of typographic designing and, for that matter, any other designing. The most effectively developed methods we have seen have been those that have rejected the use of typography as a form of applied art and have concentrated on the functional, technical, and economic factors which are involved in its use as a means of communicating information within a prescribed brief.

We contend that so long as the purposes of art are allowed to dominate the study of design, students will be robbed of an opportunity to develop the knowledge and attitudes required to deal with design problems in the area of visual communication. We believe that design problems are different in kind from those associated with the practice of either art or craft and require different forms of training from those which are traditionally associated with art and craft. The designer is no longer confined to the task of creating aesthetically satisfying objects within prescribed areas of activity and is becoming increasingly concerned with planning and co-ordination as a major function.

2.2 *Implications for secondary education.* The changing role of the designer also requires that potential design students in secondary education should be given a clearer idea of the new kinds of subjects which they will be required to study on design courses and when they practice as professional designers. This in turn means that the designer's function has to be understood by those responsible at secondary level for advice about future careers. We believe that the view of industrial design held by teachers and pupils in secondary education is still largely based on the concept of the designer as an artist, and design courses as means of refining the "artistic ability" of students who show promise of this kind at school. We believe that this view must be changed if students with the right attitudes and potential are to come forward. For this to happen, design education in colleges of art and design must be seen to be concerned with matters other than those of the art and craft room.

2.3 *The social role of the designer.* The prevailing confusion over design education has important social ramifications. We believe that the present educational pattern does not encourage the design student to

appreciate the significance of the role he has to play in the community at large. Much too much importance is attached to personal satisfaction arising from self-indulgence rather than from the reward of seeing a design problem satisfactorily solved for the benefit of others. This is only too clear in the case of typographic education where the tradition tends to encourage certain kinds of jobs which are superficially treated and involve no more than visually exciting images. Other areas of designing, of more consequence to society, are neglected. Furthermore, the emphasis on so-called originality often results in mere stylishness which disguises a complete absence of original thinking. Consequently, many extremely important but unspectacular areas of typography and graphic design, such as educational books and other visual aids, scientific papers, government regulations, reports, instructions, forms, and directional systems, all of which play an important part in our lives, are usually either not designed at all or are designed very badly.

2.4 *Economic considerations for the country.* We believe that, on economic grounds alone, this country cannot afford to tolerate bad design education any longer. Our concern here is with the role of the typographer, which is perhaps rather a special one since printing and other visual communication systems are central to the machinery of government, industry, trade, transport, education and scholarship. The efficient working of all kinds and levels of society depends to a large extent on communication by means of the printed word. We cope with an enormous quantity of material of this kind, the effectiveness of which depends to a large extent on the ability of the typographer to understand its content, order it meaningfully, and find a suitable medium for it. A pattern of design education based primarily on cultivating personal expression does little to come to terms with this problem. Most students leaving colleges of art and design this year will be ill-equipped to face up to the needs of industry today, let alone the future.

3 *The Work of the Typographer*

As stated earlier, we believe that design method in general is best studied through a specific industrial design discipline, and as far as graphic design is concerned we believe that typography is the ideal one.

The function of the professional typographer is to comm
specific information as efficiently as possible within the limi
imposed by his brief. In the first place the typographer mus
capable of analyzing "copy" and, if need be, re-ordering its
A thorough understanding of the use of English is essential f
handle efficiently any material given to him. He must equal
to advise a client as to the appropriate means of communic
A general knowledge of systems of communication as a who
therefore necessary, together with an understanding of the
logy of perception. The need to be able to discuss and analy
projects and problems with keen minds from business and i
fields suggests that the typographer needs to be articulate a
literate.

Because the typographer must produce creative and
solutions to the problems that are put to him, we must stres
point the importance of stimulating the student's imaginat
as training his analytical powers. A course which neglected
favor of purely scientific and technical studies would be gro
unbalanced. We recommend that any complementary stud
designed to avoid this imbalance should be connected whe
with the student's main field of study. To quote a single exa
historical topic can on its own be a disciplined and imagina
of study, but when related to the typographer's other activi
enrich and expand his appreciation of them.

Having studied a client's requirements and having, from
experience in this field, arrived at an efficient and creative
to the problems raised, the typographer will next advise the
on production methods in relation to such factors as costing
ing, quality control, and allocating priorities. The typogra
thus the student of typography, has to be informed of every
of the printing and allied industries—methods of typesettin
and binding, materials, processes, trade services, and so for
typographer will be acting as planner and co-ordinator of a
city of processes and the link between them and his client.
therefore be conversant with the theory and practice of the

Summing up, the practice of typography is not only a m
intuition or flair, but essentially a discipline and a combina
skills and functions capable of analysis. On this basis typog

be taught in a way that can be professionally and educationally valuable, while at the same time demonstrating the principles of design practice as a whole.

4 *Related Disciplines*

We do not propose a rigid structure of studies relating to graphic design, but it is very clear that many new disciplines need to be introduced, and that they would open up the possibility of worthwhile advanced work in a variety of fields. The desirability of introducing new disciplines naturally has some bearing on the plans to incorporate many graphic design courses into the educational work of polytechnic institutions. We believe that the following subjects are amongst those which have a direct relevance to the education of typographers and graphic designers, and indeed most other designers: English, mathematics, management studies, psychology, linguistics, cybernetics, technical studies, history of design.

4.1 *English*. Any designer needs to be capable of writing and speaking clearly and objectively on various aspects of design. The preparation of visuals, storyboards, process artwork, and working layouts has to be augmented by concise, but comprehensive, written and oral data. A designer who is responsible for fact finding in relation to a project must be able to present his findings in a form in which they can be used by others. Furthermore, the typographer is closely involved with editorial decisions and must have a clear understanding of the meaning of his copy before he can begin to order it. For these reasons we recommend that all courses in typography include provision for students to develop fluency and clarity of expression in written and spoken English and that, where possible, this should be linked with practical work in design.

4.2 *Mathematics*. Calculations and measurements are normal routines of typography and demand a competence in simple mathematics. The preparation of specifications is an important aspect of design, and students of typography must be familiar with methods of calculating costs and quantities and ways in which these can be expedited by the use of formulae and slide-rules. The typographer is also concerned with communicating statistical data, and this means that he must be able to understand the general principles of statistics and statistical graphs. Descriptive geometry, augmented by practice in technical drawing, is clearly of value to graphic designers who frequently work in three dimensions. Particular areas of mathematics, such as mathematical logic, analogue geometry and binary notation, are linked with cybernetics. We believe that mathematics is as central to typography as it is to many other areas of design and technology.

4.3 *Management studies.* Definitions of management are often synonymous with definitions of design. The functions of management have been defined as planning, organizing, directing, co-ordinating, and controlling. These are also important functions of the designer, and it is commonplace for designers to fulfil executive roles in organizations. Training in the principles and techniques of effective management, administration, and planning is valuable to the young designer because such principles are analogous to those of good practice in design. In a number of colleges students of graphic design are already being taught the principles of particular management techniques of analysis and planning. Through such studies students can be helped to develop their own design philosophies; they can learn something about organizational structure, acquire insight into the roles and activities of managers, and learn to appreciate that implementation of a project is equal in importance to, and more complex than, its visualization. Management studies, including matters of finance, law, and modern techniques of planning should be integrated with the study of professional practice in typography and graphic design courses.

4.4 *Psychology.* We believe that the study of the processes of conceptual thought, learning, perception, memory, cognition, and other aspects of human behavior are of great importance to the typographer and graphic designer and should be included in his education. In particular, all students should have some understanding of perception in relation to reading and should be familiarized with work that has been done in the field of legibility and allied problems.

4.5 *Linguistics.* The typographer is primarily concerned with ordering verbal information and ideas. Until recently the traditional ways of ordering such material had changed very little, but the development of algorithmic methods for the presentation of information during the

last decade has opened up entirely new approaches which should be very much the concern of the typographer. Similarly, the typographer has much to learn from the new discipline of linguistics, which is concerned with the study of the function and structure of language in general. Typography can legitimately be seen as "visual linguistics" and should be studied in relation to the wider use of language.

4.6 *Cybernetics.* The interrelated fields of cybernetics, computing, and automatic data processing are the leading edge of contemporary technology and are central to a large and important sector of typographic engineering. Unless students of typography are introduced to the principles of cybernetics, they run the risk of becoming redundant within a few years of leaving college. Access to a computer is desirable but not essential in order to train students in the principles of computing and programming. Such simple apparatus as a typewriter and stencil-duplicator can be used for a communication system which can provide a basis for introductory experience in the disciplines of systems analysis and systems programming.

4.7 *Technical studies.* For many reasons this is perhaps the most difficult kind of study to implement in full-time education. We are conscious that some teachers attach little or no importance to technical studies, and we know that many teachers are largely ignorant of technical matters and are not in touch with recent developments. We believe that technical studies in typography should not be limited to the operations of printing but should extend into other areas of the communications industry. It seems to us absurd that design students in any field should be uninformed of relevant equipment, materials, processes, standards, conventions, and terminology.

4.8 *History of design and technology.* We believe that students of design are most likely to be interested in an historical study arising from their practical work. The typographer and graphic designer should study some aspects of the history of graphic communication, design, and technology in relation to social, economic, political, and intellectual developments. A study of the history of letterforms could increase a student's sensitivity to typefaces in use at the present time and help him to come to terms with future developments. We do not accept that analysis of history is irrelevant to the education of designers and believe that such a study can play a valuable part in opening up fields outside a student's immediate experience. It is also a means of making students aware of the elementary tools of scholarship and of encouraging critical judgment.

5 *Implications for Higher Education*
As mentioned above, this document is not concerned with making specific proposals relating to the implementation of courses, but more with general conclusions that have emerged from our discussions.

5.1 *Entry requirements*. We do not wish to state categorically which subjects should be required of students who enter design courses, or what level of achievement should be expected, but we do believe that some requirements will have to be made. We make three general observations.

First, there is at present a tendency for good applicants with scientific interests not to look in the direction of design. Ways must be found to change this situation if students with such potential are to come forward.

Secondly, the new approaches to teaching science and mathematics in primary and secondary education are particularly relevant to the thought processes which will be required of designers, especially in relation to the inter-disciplinary character of design operations demanded by new technological developments and managerial techniques. We are certain that unless students have a foundation in these disciplines at school, higher design education cannot properly fulfil its role.

Thirdly, design education must provide opportunities for mature students who need to change direction. We believe that provision for such students must become a feature of design courses, and that high level studies will benefit from an infusion of maturity (as was shown during the immediate post-war period in many areas of further education). Clearly, entry requirements demanded of this type of person would not be solely dependent on formal academic qualifications.

5.2 *Equipment*. A generous supply of elaborate and expensive equipment is no substitute whatsoever for a sound, imaginative approach to teaching typography and graphic design. Many of our members have been disturbed by the undue emphasis placed on prestige

equipment in some schools and have found that this can so easily obscure some of the more essential thought processes of design education. Machinery and other major items of equipment can, and ideally should, play an important part in the education of students of typography and graphic design, but the first priority should be to discover what they are needed for. Only then will it be seen what kind of equipment can be most satisfactorily used to serve the educational purposes in mind.

5.3 *Links with industry*. We are very much in favor of forging strong links between educational establishments and the printing and allied industries. Such co-operation would go some way to solving the problem of familiarizing students with modern industrial processes without the need for schools and colleges to incur enormous and unnecessary capital costs. It would also help students to understand some of the social and organizational problems of industry. Students should spend some part of their vacations working in a variety of branches of the printing and allied industries, and ways must be found for students to spend periods working under supervision in industry as part of their courses.

5.4 *Staffing*. The re-training of existing staff and the appointment of suitable new staff (including some with industrial experience) are clearly major issues arising from these proposals. We are only too aware from our own discussions over the last two years of the inadequacies of our own education and training which, in the majority of cases, has been visually oriented. The contribution made by professional designers from industry to Working Party meetings has been particularly valuable, and we are sure that industry itself must be prepared to encourage the involvement of its personnel in the overall pattern of design education. There is, however, no substitute for full-time teachers, and the profession must be prepared to come to terms with many new disciplines which may perhaps be foreign to its nature and past experience.

6 *Urgency*
We welcome the current re-appraisal of design education and cannot overstress the urgency of dealing with these problems.

Postscript: International Dialogue
This report is adapted from the first Interim Report of the Working Party, published at its third study conference at Stafford in November 1968; earlier conferences were held in 1967 and 1968 in London and Manchester. The Working Party's steering committee is preparing pictorial documentation of approaches to typographic teaching for publication in a subsequent issue of the *Journal*, and the Working Party is interested in exchanging views with educators in other countries. Correspondence should be addressed to the secretary: Miss Gillian Riley, MA, 9 South Villas, Camden Square, London NW1, England. The Interim Report is available in booklet form (single copies $2.00, bulk orders above 30 copies $1.00, prepaid) from the secretary.

USA: Typography in Journalism School Curricula

William R. Lindley

Typography has a minor and far from consistent place in the curricula of major American schools of journalism. That may be gathered from a survey of schools accredited by the American Council on Education for Journalism. There are 55 accredited schools, including most of the larger ones; 50 replied to the survey, completed in 1968.

There are several reasons why journalism schools offer instruction in typography, and oddly diverse reasons they are.

Some students in news-editorial sequences are required to work with type so they may be better editors. Other schools evidently think future editors don't need to know, from laboratory experience, how to handle type. These schools give some attention to the matter in lectures, or organize field trips to printing plants.

Other schools think it is their advertising students who need laboratory experience with type, but make such courses optional for those in the news-editorial sequence. Of course there are still other schools which think students in both subjects need the experience. And then, incredible as it may be, one school requires the course of public relations students only.

All told, 35 of the schools replying offered courses in typography, while 15 did not.

Here are the survey questions and answers, together with some marginal comments by professors (whose replies were to cover typography as taught to journalism majors only).

1. Does your journalism major curriculum list any courses in typography? Yes, 35; no, 15.

*2. If so, how many hours total in catalog? (Please specify quarter or semester hours.)** Two semester hours, 10 replies; three semester hours, 6;

* Three *semester* hours normally means a class that meets for three hours a week during a semester school term (one-half of a school year); three *quarter* hours normally means a class that meets for three hours a week during a quarter school term (one-third of a school year). Laboratory periods normally meet for two hours a week for each hour credit.

three quarter hours, 5. These were the only choices marked by more than one school. Total hours for individual schools ranged to 10 and 11 quarter hours and, in one case, to 24 semester hours. Comments:

"We teach quite a bit of typography in our copy-editing class and also in Advertising Copy and Layout."

"We list one course specifically, but we teach production and typography for all students as part of editing."

(No courses in catalog.) "Included in two editing courses."

"We require a course offered in the Industrial Arts Department."

(No courses in catalog.) "We have fully competent faculty (including former ITU member) and include elements of typography in copy editing and advertising layout. Students see hot type in own plant where *Daily* is produced, cold type on field trips."

"Only one course in the school is called typography: a two-semester-hours laboratory course, required of advertising majors, hand-set foundry type mostly, emphasis on design. But typography plays a large part in five other courses: Advertising Layout and Copy, three semester hours; Newspaper Production, two hours; History of Books and Printing, two hours; Book Design and Production, two hours, and Magazine Production, two hours. Newspaper Production is also a laboratory course. Students make up pages of cold type as well as of hot. This course is required of news-editorial majors. Advertising layout is required of advertising majors and magazine production of magazine majors. The other two courses are merely elective.

"I teach four of these courses, and try to cover photo and computer composition; but we don't have the requisite machines to give students direct laboratory experience, and I'm not sure we desire to acquire them. The hopeful development of educational policy here is away from trade-school approaches."

"Only as part of editing. No type lab."

"We have a course in our catalog which is entitled Typography and Printing. Probably Typography and Layout or Design would be better because that is where the main emphasis lies."

"We believe our students should know how to use type as a design tool, but not as a printer. Therefore, we do not include any typesetting in this course. The laboratory work is keyed to the design and layout emphasis."

"We handle typography as part of our course in editing and course in advertising communication."

3. Are courses required? Yes, at least in one sequence, 25; no, 10. Many answers conditional. Comments:

"Required for advertising majors."

"Optional for radio-TV and advertising."

"Required for advertising sequence; optional for remainder."

"Required only for public relations majors; optional for all others."

"Required for advertising and news; optional for broadcast."

"Required for advertising majors; optional for news-editorial."

"Required for ad majors; optional for other students."

"Required of ad majors only."

4. In typographical instruction, your students learn to compose work in: A. Handset lead type, 28. B. Handset type and slugs of cast type, 16. C. Cold type, 21 (Specifying impactset type, 11; specifying photoset type, 12). D. Course requires no lab, 4. Comments:

"We teach no skills. Confine the course to a knowledge of procedures and where these procedures fit into other courses. We do most of our lab work on paper in creating ideas, layout, etc. A knowledge of processes is given with emphasis on their part in total journalism program."

"The processes are explained but the students do not perform the operations."

"Do not do any actual composition."

"After this semester students will receive instruction in offset."

"Cold type in nearby offset plants. Hope to have basic equipment in our own lab soon."

"Use hand-set lead type less and less."

5. Would your school be interested in sending a faculty member to a five-day American Newspaper Publishers Assn./Research Institute seminar where he could be updated on all the production breakthroughs of the past few years? [The writer had suggested this to ANPA/RI and had received expressions of interest. The idea is still in the talking stage.] Yes, 41; no, 7. Some responses conditional. Comments:

"We'd be very much interested in participating with ANPA; one of the real drawbacks of journalism education is that we have not projected a clear vision of what the newspaper (or any other medium) is likely to be like, say, 20 years from now. Our accreditation team criticized our typography class and we've given serious consideration to abandoning it. Most likely we'll incorporate it with editing."

"Useful to schools in range, where access for *students* would be practicable."

"Yes, if some emphasis could be put on *future* breakthroughs."

"Typographic instruction today should include all the processes now in use for converting the written or spoken word to the printed page in attractive, legible, readable form. Because of the many complicated processes in use today, second guesses on typographical arrangement, even if possible at all, are much more costly and time-consuming. We can no longer insert a lead or two between Linotype slugs to improve legibility and fill available space.

"There are still many fundamentals: Typefaces, sizes, classifications; typeface selection, typographical arrangements, space limitations, etc., that can be taught in yesterday's type lab; a hand-set type lab by itself isn't sufficient."

It does appear as a result of the survey that schools of journalism recognize the importance of typography to parts of their curricula. However, they are far from agreement on the who, what, when, where, why and how of typographical instruction.

William R. Lindley is chairman of the Department of Journalism at Idaho State University (Pocatello, Idaho 83201). He studied printing in a technical secondary school, then took Bachelor's and Master's degrees in journalism from the University of Oregon. He was on the editorial staffs of several western newspapers before turning to teaching some ten years ago. A briefer report on his survey appeared in *Journalism Quarterly*, Spring, 1968.

Résumé des Articles

Traduction : Fernand Baudin

Les premiers livres d'alphabets de la Renaissance *par Millard Meiss*

Les traités sur le dessin de l'alphabet sont une innovation des débuts de la Renaissance. Ils reflètent un univers régi par des proportions numériques et de forme géométrique selon les conceptions du temps. Les relations réciproques des hommes et de leurs théories sont étudiées et illustrées. Certes, Félice Feliciano fut l'initiateur de ces traités; mais il apparait qu'Andrea Mantegna joua un rôle important sinon le rôle principal dans la restauration de la capitale romaine.

La lecture électronique des textes imprimés à la main
par John H. Munson

Cet article décrit les étapes et les résultats d'une étude sur la lecture électronique de textes imprimés assez négligemment à la main. Les opérations du balayage séquentiel, de l'identification et de la classification des caractères sont décrits. Parmi les nouvelles techniques expérimentées : un dispositif de pré-identification composé exclusivement de détecteurs étalonnés; des indicateurs de tolérance polyvalents tant avant qu'après la classification; en vue d'une plus grande fidélité dans l'identification, on a mis en parallèle des systèmes de pré-classification qui sont normalement indépendants; le contexte a été préalablement analysé en vue d'une meilleure lecture électronique. L'étude donne également une bibliographie étendue concernant la lecture électronique des imprimés à la main.

L'identification des signes sur papier *par R. M. N. Crosby*

On sait relativement peu de choses sur la manière dont un enfant apprend à lire' c'est-à-dire, sur ce qui se passe dans son esprit. Tout en étudiant de quelle façon l'apprenti lecteur apprend à distinguer les différents symboles graphiques, cet article examine plusiers problèmes connexes : en quoi la période pré-scolaire retarde-t-elle l'enfant dans ses premiers efforts de discrimination entre les signes alphabétiques ? Comment l'enfant apprend-il à les distinguer ? A distinguer les mots ? Quelle corrélation y a-t-il entre écriture et lecture ? Plusieurs programmes de recherches en ce sens sont examinés.

Lisibilité relative en Télévision des caractères MITRE, de Leroy et Lincoln
par Donald Shurtleff

La lisibilité des symboles alphanumériques Leroy a été comparée avec celle d'un nouvel assortiment, le Lincoln/MITRE, sur un écran de télévision avec des trames de 8, 10, 12 et 14 lignes de hauteur par signe. Le nouvel assortiment n'était pas plus lisible dans aucune de ces trames. Si les résultats ne sont pas favorables, l'expérience n'en a pas moins fourni des données utiles en vue d'améliorer la lisibilité des caractères destinés aux titrages à la TV. Il serait souhaitable que ces nouvelles techniques soient mises à profit.

Kurzfassung der Beiträge

Übersetzung: Dirk Wendt

Die ersten Abhandlungen über das Alphabet in der Renaissance *von Millard Meiss*

Abhandlungen über die Gestaltung des Alphabets waren eine Neuerscheinung der frühen Renaissance und geben die Auffassung jener Zeit wieder, daß die Welt durch Zahlenverhältnisse und geometrische Formen geordnet sei. Die Beziehungen zwischen den verschiedenen Männern und ihren Theorien werden diskutiert und illustriert. Zwar hat Felice Feliciano mit diesen Abhandlungen äber das Alphabet angefangen, aber es zeigt sich, daß Andrea Mantegna eine bedeutende Rolle (wenn nicht die Schlüsselposition) bei der Wiederentdeckung des lateinischen Buchstabens innegehabt hat.

Das Erkennen handgeschriebener Druckschrift mithilfe von Computern *von John H. Munson*

Dieser Aufsatz beschreibt die Methoden und Ergebnisse eines Projektes, welches das Erkennen von relativ unreglementierter handgeschriebener Druckschrift zum Ziel hatte. Techniken des Abtastens, der Extraktion von Chrarakteristiken und der Klassifizierung von Schriftzeichen werden beschrieben. Unter den neuen Verfahren, die untersucht werden, ist ein Vor-Analysator zur Extraktion typischer Merkmale, der ganz aus lokalen Kanten-Detektoren besteht, die Benutzung mehrwertiger Verläßlichkeits-Indikatoren vor und nach der Klassifikation, die Kombination parallel, aber unabhängig voneinander arbeitender Vor-Klassifizierungssysteme zum Zweke erhöhter Genauigkeit bei der Zeichen-Erkennung, und der Gebrauch einer anwendungs-orientierten Kontext-Analyse. Zwei dicke Akten handgeschriebener Druckschrift-Daten werden beschrieben und Ergebnisse bezüglich ihrer Lesbarkeit angegeben. Dazu kommt eine umfangreiche Bibliographie über das Erkennen handgeschriebener Druckscrhift.

Das Erkennen von Zeichen auf Papier *von R. M. N. Crosby*

Man weiß verhältnismäßig wenig darüber, wie ein Kind lesen lernt—d.h., was in seinem Hirn vorgeht. Dieser Artikel handelt davon, wie der Lese-Anfänger graphische Symbole zu unterscheiden lernt, und von verschiedenen damit verbundenen Problemen: In wiefern behindert die Vor-Schulerfahrung das Kind beim anfänglichen Erkennen von buchstabenähnlichen Formen? Wie lernt es zwischen Buchstaben zu unterscheiden? Und zwischen Wörtern? Welche Beziehungen bestehen zwischen Lesen und Schreiben? Verschiedene Forschungsprogramme zum Lesen werden diskutiert.

Die relative Lesbarkeit der Schriftschnitte Leroy und Lincoln/MITRE auf dem Fernseh-Bildschirm *von Donald Shurtleff*

Die Lesbarkeit der alphanumerischen Standard-Zeichen der Leroy wurde verglichen mit der einer neuen Schrift, der Lincoln/MITRE, auf einem Fernseh-Monitor bei einer Auflösung von 8, 10, 12, und 14 Zeilen auf die Symbolhöhe. Die neue Schrift war der Leroy in keinem der geprüften Auflösungsgrade überlegen. Trotz dieses negativen Befundes wurden Einsichten gewonnen, wie man den Entwurf von Schriftzeichen zum Zwecke deutlicherer Fernseh-Übertragung verbessern kann. Es wurde empfohlen, diese neuen Entwurftechniken bei künftiger Arbeit an Fernseh-Darbietungen zu berücksichtigen.

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I certify that the statements made by me above are correct and complete. (signed) Merald E. Wrolstad, *Editor and Publisher.*

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Donald A. Shurtleff has been a member of the Technical Staff, Digital Systems Department, the MITRE Corporation (Bedford, Mass. 01730) since 1961. He received his doctorate in experimental psychology from Boston University in 1962. Dr. Shurtleff is currently working on problems of perceptual quality of visual displays with emphasis on symbol legibility and related visual tasks of system operators.

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Line Scan Standards for Characters and Symbols: a Practical Study, *C. J. Duncan*
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