

# VISIBLE LANGUAGE

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COVER: An ultra-violet photograph of the verso (hair side) of a parchment palimpsest fragment showing both the original Greek uncial writing of Plato's *Parmenides* 152D, and the later rude Coptic writing on top. The fragment, recently discovered by Dr. William H. Willis of Duke University, has been identified as dating from the second century A.D., probably before A.D. 150. Coming between known second-century writings of Greek authors on papyrus and fourth-century biblical codices, it is considered to be an important link in the evolution of the book in Western literature. Photograph by Hendrik A. van Dijk, Jr., Duke Medical Center.

*Additional information on the parchment fragment is given on page 144.*

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# Linguistic Features of Scribal Spacing

Virginia J. Cyrus

In contrast to the regularity of the letterforms in hand-produced Old English manuscripts, the scribal spacings show great variation in both size and positioning. Examination of the spacings in the Tollemache manuscript of Alfred's *Orosius* reveals extensive patternings which can be shown to correspond with such linguistic features of the text as syntactic structures as they are identified by immediate constituent analysis. Thus, the manuscript provides graphic evidence of non-segmental features of the language which before were only indirectly inferable.

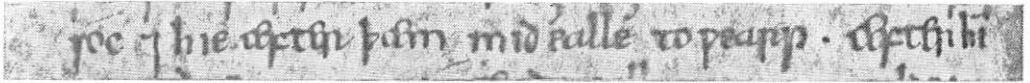
Some ancient hand-produced manuscripts may contain linguistic data which mechanically prepared language records do not. Because scholars generally have approached manuscripts prejudiced by the assumptions of modern reproductive processes, their attention has been focused primarily upon phonologically distinguishable morphemes as represented by alphabetic letterforms, or, rather imprecisely, upon words. Type-produced editions of a manuscript essentially provide only a standardized notation of the segmental text; that is to say, they reproduce a manuscript as a string of words, often with punctuation and capitalization supplied according to modern conventions. Close examination of one manuscript, the Tollemache manuscript of King Alfred's translation of Paulus Orosius's *History of the World* (British Museum Additional Manuscript 47967),<sup>1</sup> reveals other regular features not represented in machine reproductions. Apparently as the scribes attempted to reproduce language visually, they incorporated certain linguistic features into their transcriptions which have since been normalized or eliminated due to the mechanical demands of the printing process.

The Tollemache manuscript was selected for this study for a variety of reasons. First, because Alfred was intent on interpreting meaning rather than producing a slavish word-for-word translation,

he took great freedom with his Latin original, thereby furnishing today's scholars with a text which represents an extended composition by a native speaker of Old English. As a result the Tollemache is one of the few manuscripts upon which the grammar of Early West Saxon, the traditional norm of Old English, was constructed. Furthermore, paleographic analysis indicates that this manuscript was transcribed at the center of origin, presumably Winchester, within the quarter-century immediately following the literary activity of Alfred and his circle. Moreover, both the formation of individual symbols and the general formation of letters indicate that the manuscript was prepared by a single contemporary scribe, who, it is reasonable to assume, was a native speaker of English, and thence thoroughly familiar with the language. Because of the minimal possibility of corruption or contamination of the original text, this manuscript provides a unique record of the use of the English language 1,000 years ago.

Anyone examining the manuscript must be struck immediately by the incredible regularity of the hand-produced letterforms. Even though some pages are slightly more crowded than others, there is almost no difference in the formation of any given grapheme (loosely speaking, letterform) in its numerous occurrences on any page or series of pages. Throughout the manuscript the linear measurements of various letters in relation to each other are consistent. The linear measure of a non-terminal occurrence of the triple stroke *m* or the *æ* ligature is almost always exactly twice that of the mid-word appearance of the single stroke letters *i* or *l*. Halfway between these two extremes is the space allotted to those letters made with two vertical penstrokes—*h*, *n*, *u*, and *r*. Most graphemes made with one circular stroke or combining a straight stroke and a circular stroke—*b*, *d*, *ð*, *f*, *o*, *p*, *s*, *þ*, *ƿ*, and the low forms of *c* and *e*—take virtually equal space along the line. The linear measurements of various occurrences of *a*, *g*, *t*, and *x* do differ slightly, but this deviation seems to be dependent on and consistent with the sequential environment in which they appear.

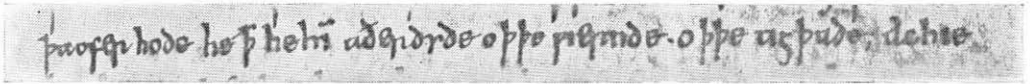
In contrast to the exceptional regularity of the size and shape of the letters, the linear measure of the spaces separating letters or groups of letters varies noticeably. About 8% of all spacings can be attributed to such arbitrary causes as manuscript damage, erasures,



sóx 7 hicæfter þæm mid ealle to wearp. æfter hi(m)



þa oþre to scipun oðflugon. 7 raðe þæs þe ham coman



þa oferhode he þ(æt) he hi(m) aðer dyde oþþe wiernde. oþþe tigþade; Ac hic

Figure 1. These representative lines illustrate the uniform formation and proportionate regularity of the graphemes relative to their environments. The irregularity of the size and placement of the spacings is especially apparent when the manuscript line is compared to modern lexical spacing. From *The Tollemache Orosius, Early English Manuscripts in Facsimile*, vol. III. Reproduced by the kind permission of the publisher, Rosenkilde and Bagger.

imperfections in the vellum, interlinear corrections and the right margin line end. Even when these indeterminate spacings are disregarded, the scribal spacing still is characterized by a remarkable irregularity compared to the regularity of the letter shapes.

The scribal placement of spaces does not always comply with the modern principle of identifying each lexical unit, or “word,” by spaces immediately preceding and following it; this becomes readily apparent when the manuscript is compared with Henry Sweet’s edition of the text.<sup>2</sup> In the manuscript articles, prepositions, the negative particle, pronouns, determiners, and conjunctives frequently are not separated by space from the following “word.” On the other hand, one eighth of all spaces occur within “words,” although the sequence of letters between two spaces is usually at least a morpheme, a linguistically meaningful unit of speech. Also the

positioning of spacings shows a consistent relationship to certain classes of morphemes. A space commonly appears between the elements of a compound; prebases, postbases, and prefixes frequently are separated from their bases by spacing, while inflectional suffixes almost never are separated. Tabulations of the occurrences of different spacing widths in various morphological environments indicate that the variation of scribal spacing definitely is not random.

Scholars who work with manuscripts have noted correspondence between scribal spacing and certain linguistic signals. In his *Old English Grammar*, Alistair Campbell says, "Word-division is inconsistent in Old English manuscripts, for the accentual group obscures the word, and proclitics (e.g., articles and prepositions) are frequently joined to the following word, or divided from it by a space less than that which normally divides words. On the other hand, compounds are frequently divided into their component parts."<sup>3</sup> Although Campbell does not pursue this point, his identification of the relationship between the spacing patterns and "accentual groups" provides the key to the significance of the scribal spacings.

Examination of the manuscript in this light reveals that both the positioning and the variation of the width of the scribal spacings display extensive patterning which coincides with syntactic (word order) as well as morphotactic features of the text. Briefly, morphotactics describe the distribution of the basic elements of speech, both segmentals, that is recurrent and meaningful sound sequences such as bases (root words), affixes, and pre- and post-bases; and supra-segmentals, that is, prosodic features like stress, pitch, and juncture.

Even though page 13 of the manuscript (Fig. 2) does not provide the most striking example of spacial patterning, it was selected as an illustration for several reasons. It provides samples of both very simple sentence structure (11.1—21) and more complex constructions (11.22—31). Also the vocabulary on this page should seem less

Figure 2. Page 13 of *The Tollemache Orosius, Early English Manuscripts in Facsimile*, vol. III. Reproduced by the kind permission of the publisher, Rosenkilde and Bagger.

episculand 7 be eastan manowalonde 7 pyle lond . 7 be  
 eastan þam pinte daru jupe lu pason zotan be nonþan  
 westan manowara pindon dala mēac þan 7 be eastandala  
 mēac þan pindon hopuzt 7 be nonþan dala mēac þan pin  
 don suppe 7 bēstcun him pyle bēnonþan honot 7 ma  
 þaland 7 bēnonþan maþalonde 7 þi mēnde oþra bēnonþan  
 þe pēn . bēstcun þuðe þu 7 þe 7 cap pēct 7 eajim þe þe rmb  
 utan þe land bēstcunna . 7 bēnonþan him 7 þe 7 þe ean  
 þanon hæc oþt 7e 7 be eastan him 7 bēnonþan pindon nonþ  
 dene æþn ze onþan mananlandū ze on þam izlandum 7  
 be eastan him pindon apdpede 7 bēstcun hū 7 eale mēka  
 þe 7e 7 eald pēana þum dæl . nonþdēne habbad bēnonþan  
 him þone ilcan þe eajim þanon hæc oþt 7e 7 be eastan  
 him pindon oþt paldode 7 apdpede bēstcun oþt habbad  
 bēnonþan him þone ilcan þe eajim . pineday 7 þurgen  
 car 7 be þe þan him pindon he þeldun . þurgen dan habbad  
 þone þe eajim bēstcun him 7 sþen bēnonþan 7 be eastan  
 him pinte 7 þi mēnde 7 bēstcun him suppe . sþen habbad  
 bēstcun him þone þe eajim oþt 7 be eastan him 7 þi mēnde  
 7 bēnonþan him 7 þe þe pēctcūne 7 pēctcūne . 7 bēstcun non  
 þan him pindon 7e pēnde þinne 7 be pēctcūne nonþ mēan .  
 chēthē þe þe hū hlaþonde æþpede 7 mēn 7e þe he ealra  
 nonþ monna nonþ mēn bude . hū þe þe þe he bude  
 on þan lande nonþ pēandū þi þa pēctcūne . he þe þe  
 þe þe þe land 7e sþe þe lūn 7 nonþ þonau . uchic 7 eal  
 rēte buton on þe þe stopum sþe mēlū pēctcūne þi  
 mē on hūctode on pēctcūne 7 on þum þe on þe þe  
 bēstcūne þe he þe þe þe he æt þumum eajim þe þe  
 þe þe þe hūctode þe lūn nonþ þe þe lūn 7e oþe  
 hūctode 7e mēn bēnonþan þam pēctcūne bude  
 þe þe nonþ þe þe bēstcūne lande læ him eal þe þe

\*  
 Hic incipit  
 Peri plus  
 Othheri.

foreign than most to readers unfamiliar with Old English. Finally, since Alfred's description of northern European geography and his account of Ohthere's voyage are supplements to the Latin original, they represent totally free composition in Old English by a native speaker.

In the following discussion of the text a more or less arbitrary code will be used to indicate the measure of the scribal spaces according to the following scale:<sup>4</sup>

- 0 not enough room for a single penstroke between letters at a morph boundary which elsewhere is marked by spacing.
- 1 the width of a penstroke. This is the standard size of the space between most non-contiguous letters within a single syllable.
- 2 the width normally allotted to a grapheme formed with a single penstroke, such as *i* or *l*, when it appears internally in a morpheme. Spaces of this size occur most frequently between words.
- 3–6 multiples of the above.
- 9 line terminal.

Of the 38 major syntactic units, or clauses, on page 13, twelve end with pointing and all but three end with a space of at least size 3. Two of the exceptions are the closely linked complex constructions "he sæde þeah þæt" (he said however that) and "he cwæþ þæt" (he said that). The third is the unaccountable size 1 space which separates "iglandum" from the "ǵ" (and) followed by a point at the end of line 10.

All but six units end with a space as large as or larger than any space which occurs within them. Three of the exceptions seem to be merely the result of vagaries of human transcription: the end of line 10 mentioned before; the wide space (size 5) between "be" and "norþan" at the end of line 2; irregularities not only in spacing but even in the straightness of the last line on the page. The other three exceptions are probably more significant: in line 22 a size 4 space sets off the appositional "ælfrede cyninge" (Alfred the king); the two size 4 spaces on line 5, following "surfe," and on line 6, preceding "sermende," both seem to be related to the fact that in the compound constructions the verb "to be" is understood.

Close examination of one passage from midpage (11.16–21) will illustrate more clearly than generalizations the astonishing degree of correspondence between sequences identified by the spacings and

principle constituent boundaries independently inferable from syntactic features. Boundaries of major syntactic constituents, or sentences, and the internal relations of constructions are signalled by word order, function words, parts of speech categories and inflections. Using these syntactic signals, the boundaries of the principle constituents are marked for these lines. To facilitate modern pre-conceptions, spaces in this sample are positioned on the basis of lexical units or words; superscript numerals indicate the measure of the scribal spacing at the point of each syntactic cut. The first cut produces the major syntactic units or clauses:

<sup>5</sup>burgendan habbað þone sæs earm be westan him & sweon be norþan<sup>4</sup> / & be eastan him sint sermende & be suþan him surfe.<sup>5</sup> / sweon habbað be suþan him þone sæs earm osti & be eastan him sermende<sup>9</sup> / & be norþan him ofer þa westenne is cwen land.<sup>4</sup> / & be westan norþan him sindon scride finne & be westan norþ menn.<sup>9</sup> /

*Translation:*

<sup>5</sup>Burgendans have the sea arm to the west of them and Swedes to the north<sup>4</sup> / and to the east of them are Sermedes and to the south of them Surfes.<sup>5</sup> / Swedes have to the south of them the sea arm Osti and to the east of them Sermedes<sup>9</sup> / and to the north of them over the waste is Queenland.<sup>4</sup> / and to the west-north of them are Scride-finns and to the west North-men.<sup>9</sup> /

Size 5 spaces with pointing both precede the passage and separate its two main thought units, the Burgendan and the Sweon. Of the five major syntactic units (independent clauses), three end with pointing and all end with size 4 or 5 spaces or at the end of a manuscript line. Further cutting produces the following boundaries:

<sup>5</sup>burgendan habbað þone sæs earm be westan him<sup>3</sup> / & sweon be norþan<sup>4</sup> / & be estan him sint sermende<sup>3</sup> / & be suþan him surfe,<sup>5</sup> / sweon habbað be suþan him þone sæs earm<sup>2</sup> / osti<sup>3</sup> / & be eastan him sermende<sup>9</sup> / & be norþan him<sup>3</sup> / ofer þa westenne<sup>4</sup> / is cwen land.<sup>4</sup> / & be westan norþan him sindon scride finne<sup>4</sup> / & be westan norþ menn.<sup>9</sup> /

These markings distinguish the major constructions and their main constituents. The correspondence between these syntactic boundaries and the sequences identified by the spacings can be seen if the

numerals which indicate the widths of all manuscript spacings are superimposed.

<sup>5</sup>burgendan<sup>2</sup> habbað<sup>9</sup> þone<sup>2</sup> sæs<sup>2</sup> earm<sup>2</sup> be<sup>0</sup> westan<sup>2</sup> him<sup>3</sup> / &<sup>2</sup>  
sweon<sup>2</sup> be<sup>0</sup> norþan<sup>4</sup> / &<sup>2</sup> be<sup>2</sup> eastan<sup>9</sup> him<sup>2</sup> sint<sup>2</sup> sermende<sup>3</sup> / &<sup>1</sup>  
be<sup>0</sup> suþan<sup>2</sup> him<sup>2</sup> surfe.<sup>5</sup> / sweon<sup>2</sup> habbað<sup>9</sup> be<sup>0</sup> suþan<sup>2</sup> him<sup>2</sup> þone<sup>1</sup>  
sæs<sup>2</sup> earm<sup>2</sup> / osti<sup>3</sup> / &<sup>2</sup> be<sup>2</sup> eastan<sup>2</sup> him<sup>2</sup> sermende<sup>9</sup> / &<sup>2</sup> be<sup>0</sup> norþan<sup>2</sup>  
him<sup>3</sup> / ofer<sup>1</sup> þa<sup>0</sup> westenne<sup>4</sup> / is<sup>0</sup> cwen<sup>1</sup> land.<sup>4</sup> / &<sup>2</sup> be<sup>0</sup> westan<sup>1</sup> nor<sup>9</sup>  
þan<sup>2</sup> him<sup>2</sup> sindon<sup>2</sup> scride<sup>2</sup> finne<sup>4</sup> / &<sup>2</sup> be<sup>2</sup> westan<sup>2</sup> norþ<sup>1</sup> menn.<sup>9</sup> /

All spaces size 3 or larger coincide with the elementary syntactic cuts.

Rather than making further cuts, it is easier and just as revealing to consider the locations of the least admissible cuts in terms of immediate constituent analysis, the purpose of which is to give the maximum number of actually occurring morphemes, words, or phrases at each step. Such cuts as “& sweon be / norþan” (and Swedes to / the north) or “ofer þa / westenne” (over the / waste) do not produce constituents consistent with Old English syntax which may be inferred independently. Minimal scribal spacings usually occur at such points where major syntactic boundaries cannot be marked: “&<sup>2</sup> sweon<sup>2</sup> / be<sup>0</sup> norþan<sup>4</sup>” and “ofer<sup>1</sup> þa<sup>0</sup> westenne<sup>4</sup>.”

Such syntactic parsing does not correspond absolutely with the scribal spacings, but it would be unrealistic to expect complete consistency of any feature in a text the length of the Orosius. Furthermore, it is likely that some deviations may be affected by different features than those which generally determine spacing. For example, some spacing variations are probably determined or influenced by such factors as the stresspeak in a phrase or phonotactics, that is patterns of distribution and clustering of phonemes (sounds). One obvious example of this is the spacial separation of the contiguous vowels in “be<sup>2</sup> eastan” where the corresponding syntactic units are represented with no spacial separation: “be<sup>0</sup> norþan,” “be<sup>0</sup> westan,” and “be<sup>0</sup> suþan.”

However, this paper is concerned primarily with those features which control the pervasive systematic patterning of the scribal spacing rather than with minor patterns or inconsistencies. On the basis of the evidence and in view of the well established and systematic correlation between graphemes (letterforms) and phonemes (sounds)—even though all vowel phonemes are not distinguished in the spelling—it is unlikely that the size and placement

of scribal spacings are governed by segmental features of the text. Instead, the degree of correspondence between the various ranges of spacings and the boundaries independently inferable from syntactic signals shows that syntactic features are clearly correlated with the spacings. The correlation is to be found, presumably, in the relation of prosody and syntax.

In spoken language syntax and prosody are complementary aspects of sentence structure. The prosodic (suprasegmental) features of juncture, stress and pitch correlate with the syntactic structure of the construction as a whole and identify the constituents of that construction. The intonation features coordinate with juncture to mark the boundaries of a construction (phrase, clause, etc.); however, it is juncture, characterized either by a pause or by the prolongation of the phonemes of the final stressed syllable or by both, which signals the end of the construction. In the linear representation of speech in the Old English manuscript, widest spacing occurs at boundaries of principle syntactic constructions. The increased spacing sizes then seem to imply these boundaries, and therefore the junctures; narrow spaces, on the other hand, would deny such boundaries and indicate that juncture is inadmissible. Probably because the production of a written record of speech is a slower, more deliberate act than that of speech, the spacings in the manuscript identify the boundaries of virtually every construction as it would be signalled prosodically in speech; or in prosodic terms, the spacings signal nearly every potential juncture.

Once juncture is determined, the stress of the construction (phrase or clause) may be positioned, for the strongest stress usually occurs at or near the end of the construction. Although segmental morphemes do not have stress as an integral part of their structure, words and phrases do, for no word can be pronounced except as a phrase or part of a phrase, and individual words normally preserve the identity of their stress patterns in the context of an utterance or construction. So prosodic stress patterns are determined primarily by the morphological structure of the constituent words. The unconventional size and placement of certain spacings in the Old English manuscript, like size 0 spaces preceding or following such words as particles, determiners, conjunctives, prepositions, and even some personal pronouns, suggest that the stress pattern of the larger construction

suppresses, obscures, or overrides the individual lexical unit or word. In short, the scribe seems to have followed the phrasing of normal speech, rather than word boundaries, in placing and varying the size of the spacings.

The third suprasegmental, the pitch pattern, can be inferred when the grammatical stress is positioned, for the pitchpeak usually accompanies the strongest stress of a construction. Although it can be shifted to other positions, its precise onset is ultimately determined by the stress pattern of the phrase or its constituents, and it is always bound by a terminal juncture. Therefore, the scribe who prepared this manuscript, although possibly neither intentionally or even consciously, has left a graphic record by a native speaker of the general characteristics of Old English from which the prosody can be reconstructed.

However, syntactic constituents and correlative prosody are only two linguistic features that in all probability influenced the scribal spacing. They certainly indicate that the variations in scribal spacings are meaningful, but the full extent of the meaning will be clear only after all recurrent features and structural variables on all levels from phonological features to grammatical forms and larger construction patterns have been examined in relation to the spacings.

1. *The Tollemache Orosius*, ed. Alistair Campbell, Vol. III, *Early English Manuscripts in Facsimile* (Copenhagen: Rosenkilde and Bagger, 1953).
2. Henry Sweet, ed., *King Alfred's Orosius* (London, 1883).
3. Alistair Campbell, *Old English Grammar* (Oxford: Clarendon Press, 1959), p. 14.
4. While the existence of all kinds of pointing has been taken into account, the measure of the spaces which contain pointing has not been broken into that which precedes and that which follows the pointing itself. The measure, therefore, incorporates the pointing. Also, in determining each measure, variations in letterforms such as the trailing crosshatch of the terminal e are not taken into account. Instead, the measure is taken from the "edge" of the normalized letterform.

# The Use of the Hyphen in Printing to Indicate Divided Words

F. M. O'Hara, Jr.

The unsystematic employment of hyphenation by early printers led to the author's inspection of incunabula and reproductions of manuscripts and incunabular printing. These observations showed a gradual standardization of the typographic form of the hyphen, an evolution of the phonetic division of words from arbitrary academic rules, and a slow development of the universal employment of the hyphen to indicate divided words. These trends in the history of printing suffered a reversal during the sixteenth century, and it was not until the late seventeenth century that hyphenating practices as they are observed today were generally established.

To the ancient Greek grammarians, the hyphen was a sign (Ϸ) placed under the last letter of a word to indicate that that word and the following one were compounded together in meaning and should be read as one word. The name comes from the late Greek ἡ ὑφέν, which in turn comes from ὑφ', ὑπο, under, plus ἓν, one.<sup>1</sup> Punctuation, as we know it today, has long been attributed to the Masorites, a Jewish sect *ca.* A.D. 600 who placed interpuncts after each psalm of the Scriptures to ensure that sufficient pause for due meditation would be taken. From these various marks introduced by the Masorites, it is claimed, have devolved the major marks of punctuation. However, if punctuation was devised as late as 600, it must have achieved a rapid, widespread success, for in 799 we have Alcuin, the tutor of Charlemagne, complaining in a letter to Charles that "the use of punctuation should also be resumed by scribes."<sup>2</sup> He thereupon systematized the methods of punctuation<sup>3</sup> and reformed and standardized the Carolingian writing that had evolved from early Roman minuscule (half-uncial). This Carolingian hand was used as a model for the four following centuries and is the ancestor of our minuscule alphabet.<sup>4</sup>

Whether Alcuin's plea applied to the hyphen or not is doubtful, since it was not considered a mark of punctuation but rather an

accent mark. Witness the reference to it in Putschius' analysis of the grammar of Sergius.<sup>5</sup> Under the heading "De Accentibus" he denotes

Circumflex so  $\hat{\ }^{\circ}$ ; obviously made with downward strokes in both directions. A long mark so  $\text{—}$ . A short one so  $\text{—}^{\circ}$ . A hyphen so  $\text{—}^{\circ}$ . A comma so  $\text{,}$ . An apostrophe so  $\text{'}$ .

The use of the hyphen to indicate turnovers was instituted between the ancient Greeks and the "ancient" Romans; in Putschius' edition of Maximum Victorinus's *Ars Grammatica*<sup>6</sup> we find

. . . and therefore we allow Dasium and Psile, whom the Greeks control, to pass; because the letter H exhibits exhalation by us, which is divided into two parts, as if containing a hyphen although one will not be situated near to the H, as when we connect two words as one in speaking them, and of that they make this symbol  $\text{—}^{\circ}$ , and whenever words are turned over to the following line, they will connect succeeding letters with an accent mark, for example Turnus ut ante  $\text{—}^{\circ}$  volans.

Again in Priscian's *Caesar*<sup>7</sup> he says

A mark drawn straight from the left to the right (side), thus  $\text{—}$ . What is a *brevis linea* (short line)? A similar horizontal mark, but curved like the lower part of a circle, thus  $\text{—}^{\circ}$ . What is a hyphen? A bent mark underneath a line of writing, thus  $\text{—}^{\circ}$ ; by virtue of which we connect two words as the text requires.

Diomedes also mentions the hyphen, although not its ability to unite parts of words broken at ends of lines:

To these they add the hyphen in the shape of a gently upward curving mark beneath the line of writing and straight at the upper part  $\text{—}^{\circ}$ . This mark indicates that the letters of the two words closest to each other are pronounced as one.<sup>8</sup>

An eighth century manuscript copy of Beowulf also shows the use of the single-stroke hyphen (-) to link words to be read as one (e.g., be-ond and be-com) but not to connect divided words.<sup>9</sup>

Between these writings and the introduction of printing in the fifteenth century, the hyphen was widely used to indicate divided

words. The insular (Irish Anglo-Saxon) hand used in the British Isles until the thirteenth century employed a single-stroke character (-), the Gothic script used a double-stroke character (//), and some humanistic Italian scripts that succeeded the Gothic used a single-stroke subscript (-). According to Wright<sup>10</sup> the forms / and = were introduced into the English hand after the thirteenth century, either as embellishments of the original or as borrowings from eastern countries. This is important to our inquiry since according to Goudy<sup>11</sup> all the type fonts cut in the first fifty years of printing were based on some particular vernacular hand.

In the meantime, the use of another factor, important to the implementation of dividing and hyphenating words, was being developed, that of syllabification. According to Hale,<sup>12</sup> the Romans in syllabifying a word would put with a following vowel as many consonants as would stand together at the beginning of a Latin or Greek word. Examples of words correctly divided by this principle would be fru-ctus, ma-gnus, o-mnis, i-pse, and nu-ptus. This would appear to have been a practical rather than phonetic rule. However, Dennison,<sup>13</sup> in analyzing word divisions used in ancient (*ca.* A.D. 81 on) Latin inscriptions, found that stonecutters divided words “correctly” according to our accepted, phonetic method of word division in 84 per cent of the cases (more than 2,000 observed). Therefore, although the grammarians might have had an exact non-phonetic rule for word division, the users of the written language followed phonetic rules. Divisions other than phonetic can be considered, he reasons, to be haphazard or convenient choices.

With the implementation of printing, both the rigorous employment of the hyphen where it was called for and the “correct” division of words into syllables in turnovers fell into disuse, as can be seen from Table I. The practice of punctuation, along with the employment of hyphenation, was standardized by individual printing houses,<sup>14</sup> and it was not until the sixteenth century that attempts were made at widespread standardization in spelling, punctuation, and grammar.<sup>15</sup> As late as 1771 Luckombe<sup>16</sup> lamented that “the expectation of a settled punctuation is in vain, since no rules of prevailing authority have been yet established.” Luckombe notwithstanding, standardization and systematization was early deemed desirable, and several men did something about it. The efforts of

Aldus Manutius were not among the least of these; he issued many Greek and Latin grammars. Interestingly enough, all he had to say<sup>17</sup> about the hyphen, which he referred to as a “reliquus accensus,” was

The hyphen is a subscript mark which is placed below the end of one utterance (word) and the beginning of another if we wish to join them as in ante malorum, ante volans.

To have been left out of so prestigious a grammar seems to indicate that the use of the hyphen to indicate word division had suffered a great decline in importance. But the phonetic basis of syllabification is found to have academic approval:

What is a syllable? A combination of letters, as batra, but improperly a syllable can be made of vowels only as in eoo.<sup>18</sup>

In 1620 Hume, who is considered<sup>19</sup> to be the first to Anglicize the word hyphen, also dwells solely on the compound-word use of the hyphen:

The learned printer uses to symbolize apotrophus and hyphen as wel as a, b, c. . . . Hyphen, as it wer, a band uniting whol wordes joined in composition; as a hand-maed, a heard-man, tongue-tyed, out-roge, foer-warned, mis-reported, fals-deemed.<sup>20</sup>

It is not until Bowles (*ca.* 1750)<sup>21</sup> that we see a citation in a grammar of the use of the hyphen (-) to connect divided words. Other grammarians quickly follow. Cellarius (1768)<sup>22</sup> makes note of a mark (//) he calls the “*Divisio in fine versus*,” and Burrow<sup>23</sup> differentiates between two marks:

The HYPHEN (marked -) is also very proper to shew the Conjunction of two or more Words so connected and compounded together as not perfectly to coalesce, yet to form *almost* though not quite one Word. The Duplication of the same mark (=) is used to connect the discontinued Syllables of a Polysyllable, separated from each other by the Distance of a whole Line’s Length, for want of Room to finish the Word within the End of the former Line; and it becoming therefore necessary to complete it upon a new one.

Here we must stop to explain two phenomena that simultaneously occurred to the hyphen, developments in form and employment. As has been noted, two forms of hyphens came to the printer from his calligraphic predecessors (- and =). The first came from the Carolingian and Anglo-Saxon hands, and the second from the Gothic. The slanting of these was probably a result of quickening the act of writing rather than the borrowing of another form from another source. As can be seen from Table I, the use of - and / occur largely where the influence of Italian scripts was felt, and the employment of = and // was made where Gothic script was prevalent. Interestingly, although printing was spread through Europe predominantly by Germans used to Gothic lettering, it was only in Italy where the endemic vernacular hand initially influenced the change to the lighter hyphen form. Not until the seventeenth century is there a trend toward a standardized acceptance of the single-stroke, horizontal form (-). The evolution of the form of the hyphen is traced in Table II.

The use of hyphens at all seems to have been at first disdained by printers. Meerman<sup>24</sup> in his defense of Laurentius describes his *Donatus*, published in 1477, as having

no indications of separation of syllables at the end of a line; while, on the contrary, an instance of a divided syllable is found in the middle of the line. No signs of interpunction, and indeed no punctuations, which may be observed in other works of Laurentius, occur, although the letter i is notated here not with an accent mark, but with a dot. Lines [hyphens or dashes] are randomly straight and curved.

Talking of Laurentius' other works, he says<sup>25</sup>

Except for the *punctum* which appears in all editions, save the first Latin one, no punctuation marks appear (such as the virgula, semicolon, colon, question mark, and the division at the end of certain lines).

The use of the hyphen in the new world [“aparece com dois traços (=),”<sup>26</sup>] in the poem “Lusiados” by Camoes published in 1572 was noted by Melo.<sup>26</sup> An earlier example is found in the work of Juan Pablos. Although an example of Pablos' earliest work, *Manual*

TABLE I. *Printers' Hyphenating Practices Through the Eighteenth Century*

<i>Printer (place)</i>	<i>Work (date)</i>	<i>Rigorous Employment of Hyphen- ation</i>	<i>Form Taken by Hyphen</i>	<i>Phonetic Syllabifica- tion Employed; Comments</i>
Gutenberg (Mainz)	42-Line Bible (1450-55) <sup>a</sup>	yes	//	no
Fust and Schoeffer (Mainz)	Psalterium Moguntinum (1457) <sup>a</sup>	yes	=	no
Gutenberg (Mainz)	36-Line Bible (1458) <sup>a</sup>	yes	// and /	no; follows no rule distinguishing between the two forms
Gutenberg (Mainz)	Catholicon (1460) <sup>a</sup>			no; words divided without hypens
Rusch (Strassburg)	Biblia Latina (1464) <sup>a</sup>	no	/	no
Sweynheim and Pannartz (Subiaco)	Opera (1465) <sup>a</sup>	yes	/	no
Han (Rome)	Meditations (1467) <sup>b</sup>	no	//	no
Jenson (Venice)	Epistolae ad Brutum (1470) <sup>b</sup>	yes	/	no
Freiburger, Gering, and Krantz (Paris)	Gasparini Per- gamensis Epis- tolarum Opus (1470) <sup>b</sup>	yes	/ and //	no
De Spira (Subiaco)	De Civitate Dei (1470) <sup>a</sup>	yes	/	cannot tell
Freiburger, Gering, and Krantz (Paris)	Biblia Latina (1476) <sup>a</sup>	no	/	no
Jenson (Venice)	De Arte Gram- matica (1480) <sup>a</sup>			no; words divided without hypens
Mansion (Westimnster)	Metamorphoses (1484) <sup>a</sup>	no	//	no

Ratdolt (Augsburg)	Type Specimen (1486) <sup>b</sup>	no	/	no
Spindeler (Barcelona?)	Tirant lo Blanch (1490) <sup>b</sup>			words divided without hyphens
Caxton (Westminster)	Eneydos (1490) <sup>c</sup>	no	//	no
Koberger (Nuremberg)	Schatzbehalter der Wahren Reichtümer des Heits (1491) <sup>a</sup>	no	//	no
Thierry Martens (Antwerp)	Synonyma (ca. 1493) <sup>d</sup>	no	//	no
Olpe (Basle)	La Nef des Fous (1494) <sup>b</sup>			Words divided without hypens
de Worde (Westminster)	Opus Gram- maticus (1494) <sup>a</sup>	no	=	no
Pynson (London)	Missale ad Usum Sacrum (1500) <sup>a</sup>	no	//	no
Manutius (Venice)	Elementare In- troductorium in Idioma Graecanicum (1505) <sup>e</sup>	no	/	no
Lotter (Leipzig)	Letter (1510) <sup>f</sup>	yes	//	yes
Manutius (Venice)	De Literis Graecis ac Diphthongis (1512) <sup>g</sup>	no	/ and .	no; no differentia- tion between forms
de Brocar (Alcala)	La Cronica de Serenissimo Rey Don Juan (1517) <sup>a</sup>	no	=	no
Froben (Basle)	Sermones (1519) <sup>a</sup>	no	/	no
Manutius (Venice)	Institutionum Grammaticarum (1523) <sup>h</sup>	no	/	no
de Colines (Paris)	De Opificio Dei (1529) <sup>a</sup>	no	=	no

<i>Printer (place)</i>	<i>Work (date)</i>	<i>Rigorous Employment of Hyphen- ation</i>	<i>Form Taken by Hyphen</i>	<i>Phonetic Syllabifica- tion Employed; Comments</i>
R. Estienne (Paris)	Biblia Latina (1530?) <sup>a</sup>	yes	-	no
de Colines (Paris)	Strozii Poetae, Pater et Filius (1530) <sup>i</sup>	no	/ and =	no; hyphenation ignored when typographically convenient
Sessa (Venice)	De Recta Latini Graecique Ser- monis Pro- nunciacione (1531) <sup>j</sup>	no	= and /	no; the two forms differ in width; justification was aided by their employment or disemployment
Tagliente (Venice)	Sample (1532) <sup>k</sup>	yes	/	cannot tell
Varcosan (Paris)	De Civilibus Romanorum Bellis (1538) <sup>a</sup>	no	-	seems to attempt a rigorous appli- cation of the hyphen but misses a few times
de Colines (Paris)	De Dissectione Corporis Humani (1545) <sup>a</sup>	no	//	no
Wechel (Paris)	Tiers Livre (1546) <sup>b</sup>	yes	-	no
Giolito (Venice)	Le Transforma- tioni (1553) <sup>l</sup>	no	-	no
de Tournes (Lyons)	Biblia Sacra (1558) <sup>a</sup>	no	-	no
Day (Cordon)	The Cosmologi- cal Glass (1559) <sup>a</sup>	yes	/	yes
Blado (Rome)	Tractatus Jurus (1565) <sup>a</sup>	no	/ and //	no; / used in all- cap words; // used in body type

Plantin (Antwerp)	Polyglot Bible (1569–72) <sup>a</sup>	no	-	no
Plantin (Antwerp)	Horatius Flaccus Emendatus (1580) <sup>m</sup>	yes	= and -	yes; = outnum- bers - 26 to 1
de Gourmont (Paris)	Tableaux des Arts et Sciences (1587) <sup>a</sup>	yes	-	cannot tell
Barker (London)	The Holy Bible (1611) <sup>a</sup>	yes	//	no
B. and A. Elzevier (Leiden)	Ciceronis Opera (1642) <sup>a</sup>	yes	-	yes
vander Water (Utrecht)	Pliniana Excercitationes (1689) <sup>a</sup>	yes	-	no
University Press (Oxford)	History of the Rebellion (1704) <sup>a</sup>	yes	-	yes
Merlin (Paris)	Le Pharsale de Lucain (1766) <sup>a</sup>	yes	-	yes
Bodoni (Parma)	Atti della Solemne Coro- nazione della Insigne Poetessa (1779) <sup>a</sup>	yes	-	yes
Fry (London)	Secundi Episto- lorum (1790) <sup>a</sup>	yes	-	no

a. Sample appears in S. Morison and K. Day, *The Typographic Book, 1450–1935* (Chicago: Univ. Chicago, 1963).

b. Sample appears in A. Flocon, *L' Univers des Livres* (Paris: Hermann, 1961).

c. Sample appears in C. F. Bühler, *William Caxton and His Critics* (Syracuse: Syracuse Univ., 1960).

d. Sample appears in R. G. C. Proctor, *Tracts on Early Printing. I. Founts of Type and Woodcut Devices Used by the Printers of the South Netherlands in the Fifteenth Century* (London: Clowes, 1895).

e. A. P. Manutius, *Elementare Introductorium in Idioma Graecanicum* (Venice: Aldine, 1505).

*de Adultos*, has no word division and thus no hyphenation, by at latest 1543 he was using hyphens (*//* as well as *=*).<sup>27</sup>

Jenson supposedly had no hyphen among his type punches.<sup>28</sup> Although this is belied by the appearance of hyphenation in his later works, it would account for the absence of hyphenation in some of his books.

From the start of printing until the seventeenth century many printers were employing more than one form of hyphen on the same page, often interspersed with turnovers with no hyphenation at all. One reason for this ignoring of the hyphen seems to be that the very early printers tried to conserve paper by leaving out or abbreviating as much of the text as possible. Later, when the trade was well established and the hyphen generally employed, there was another discontinuity in its use (roughly during the late fifteenth century and the sixteenth century). This can be attributed to the run on printed books and the resulting rush to produce them brought on by the spread of literacy in the middle classes. At that time the emphasis was on production, not quality. Personnel at all levels of the publishing process were insentient to the demands of grammar: the typesetter, the printer, the proofreader, and the publisher himself. Such callousness can be seen from the lack of any “quality control” in that although the great printers from the earliest times certainly employed proofreaders and type correctors, it is doubtful that even in the beginning of the nineteenth century printers *generally* employed correctors.<sup>29, 30</sup>

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f. Sample appears in G. Dowding, *Introduction to the History of Printing Types* (London: Wace, 1961).

g. A. P. Manutius, *De Literis Graecis ac Diphthongis* (Venice: Aldine, 1512).

h. A. P. Manutius, *Institutionum Grammaticarum* (Venice: Aldine, 1523).

i. Strozius and Strozius, *Strozii Poetae, Pater et Filius* (Paris: de Colines, 1530).

j. D. Erasmus, *De Recta Latini Graecique Sermonis Pronunciation* (Venice: M. Sessa, 1531).

k. S. Morison, *On Type Designs Past and Present* (London: Benn, 1962).

l. S. Morison, *Four Centuries of Fine Printing* (New York: Farrar, Straus, 1949).

m. Horatio, *Horatius Flaccus Emendatus* (ed. by A. P. Manutius) (Antwerp: Plantin, 1580).

TABLE II. *Forms Taken by the Hyphen in Its History of Development*

<i>Form</i>	<i>Use</i>	<i>User</i>
∪	subscript	ancient Greeks
-∪-	subscript	ancient Latin
-	subscript	Carolingian minuscule
/	character	Carolingian minuscule
-	character	Anglo-Saxon hand
=	character	gothic hand and type
//	character	gothic type
/	character	roman type
-	character	standardly accepted beginning of seventeenth century

The processes operating during the first wave of standardization are well exemplified in the products of Manutius' Aldine Press. Here hyphenation occurs seemingly spuriously, and where it does occur, often employs more than one form, even on the same page. The trend of his practices is shown in Table III. There seems to be a competition between the horizontal and slanted forms of the hyphen, with the slanted form ultimately being preferred (the 1523 grammar employs it exclusively). The horizontal form never seems to have been used much more than experimentally. Where the two forms exist in the same work, their occurrence seems to have been dictated by availability. But more important is the use of the hyphen as a justification aid. First its employment or disemployment, then different forms with different widths, and then different widths of the same form were used to justify a line when a word was broken at the end of it. A good proof that this irregularity was for justification purposes occurs in a 1497 publication<sup>31</sup> where two successive lines end with the divided word "provi-dentia." However, the second line is much tighter than the first, and the typesetter accordingly omitted the hyphen there although he inserted one in the preceding line. Where hyphens of different widths occur<sup>32, 33</sup> in the same work, one is about one-half to two-thirds the width of the other. Other

TABLE III. *Hyphenation Practices of the Aldine Press*

<i>Date of Work</i>	<i>Form of Hyphen</i>	<i>Conditions of Use of Hyphen</i>
1493 <sup>a</sup>	- and /	forms have no difference in width and were employed or disemployed depending on demands of justification
1495 <sup>b</sup>	/	hyphen in divided word where needed to justify line
1495 <sup>c</sup>	-	used or not used depending on line length
1496 <sup>d</sup>	-	used or not used depending on line length
1497 <sup>e</sup>	/	hyphen used in divided word where needed to justify line
1498 <sup>f</sup>	- and /	hyphen used in divided word where needed to justify line
1500 <sup>g</sup>	/ and //	tight lines have no hyphens with broken words; // is the double employment of /, taking up twice the space for justifying purposes
1501 <sup>h</sup>	/	two widths of this same form or no hyphen at all were employed to achieve justification
1509 <sup>i</sup>	- and /	tight lines use no hyphens with broken words; - and / have different widths and are differentially employed according to how much space is left at end of line
1513 <sup>j</sup>	-	employed spuriously

a. A. P. Manutius, *Institutiones Grammaticae* (Venice: Aldine, 1493).

b. Theocritus, *Idyllia* (Venice: Aldine, 1495).

c. De Aetna, appears in S. Morison and K. Day, *The Typographic Book, 1450-1935* (Chicago: Univ. Chicago, 1963).

d. A. P. Manutius, *Aldus Manutius and His Thesaurus Cornucopiae of 1496*, transl. by A. Lemke (Syracuse: Syracuse Univ., 1958).

e. Iamblichus, *De Mysteriis Aegyptiorum, Chaldaeorum, Assyriorum* (Venice: Aldine, 1497).

f. A. Poliziano, *Opera* (Venice: Aldine, 1498).

g. T. Lucretius Carus, *De Rerum Natura* (Venice: Aldine, 1500).

h. A. P. Manutius, *Rudimenta Grammatices Latinae Lingue* (Venice: Aldine, 1501).

i. Plutarch, *Plutarchi Opuscula. LXXXVII*. (Venice: Aldine, 1509).

j. A. P. Manutius (?), *Rhetorum Graecorum Orationes* (Venice: Aldine, 1513).

printers did this also. Sessa of Venice,<sup>34</sup> a near contemporary of Aldus also employed (or disemployed) two forms of hyphen (/ and =), the second about two-thirds the width of the first, to conform to justification requirements. Simon de Colines' *Strozii Poetae, Pater et Filius*<sup>35</sup> was edited by Aldus Manutius and contains two blocks of text, one at the beginning and one at the end of the book. The first is a dedication by the editor, the second a continuation of the body. But the first is hyphenated with one of two types of hyphen (/ and =) wherever words are divided; and the second, although set in the same typeface, has but one type of hyphen (/), and words are broken without hyphenation. Lines where the hyphen is missing are tight, indicating that hyphenation was ignored for typographic convenience. No such tight lines appear in the dedication, suggesting that more care went into the typesetting of this part of the book. The employment of the single form of the hyphen might indicate a preference of the typesetter working on that segment of the text.

What influenced the earlier (middle fifteenth century) and later (seventeenth century) establishment of the use of the hyphen? For the earlier period it can only be laid to the conscientiousness of individual publishers and the academic pressure of their editors and proofreaders who, in contrast to today, were the great scholars of the times. The developments of the later period were of linguistic standardization and solidification, itself an effect of widespread literacy and distribution of printed works. The need for uniform meaning throughout a language spawned a number of historical grammarians whose influence was soon felt by the compositor. Once again emphasis was on typographic quality, both in appearance and in lexical, orthographic, and grammatical exactness, in addition to production.

1. *A New English Dictionary on Historical Principles*, V (Oxford: Clarendon, 1909), 504.

2. Cited in G. H. Putnam, *Books and Their Makers During the Middle Ages* (New York: Putnam's, 1898), p. 111.

3. W. A. Mason, *A History of the Art of Writing* (New York: Macmillan, 1920), p. 417.

4. D. M. Anderson, *The Art of Written Forms* (New York: Holt, Rinehart and Winston, 1969), chap. 4 and 5.

5. H. Putschius, *Grammaticae Latinae Auctores Antiqui* (Hanoviae: 1605), column 1834.
6. *Ibid.*, columns 1943–44.
7. *Ibid.*, column 1287.
8. Quoted in P. Simpson, *Proofreading in the Sixteenth, Seventeenth, and Eighteenth Centuries* (London: Oxford, 1935), p. 134n.
9. See A. Flocon, *L'Univers des Livres* (Paris: Hermann, 1961), p. 155.
10. C. E. Wright, *English Vernacular Hands* (Oxford: Clarendon, 1960).
11. F. W. Goudy, *Typologia* (Los Angeles: Univ. Calif., 1940), pp. 27–28.
12. W. G. Hale, *Harvard Studies*, VII, 249–271 (1896).
13. W. Dennison, *Classical Philol.*, I, 47–68 (1906).
14. *Encyclopaedia Britannica*, XVIII (Chicago: Benton, 1965), 768.
15. H. Gentry and D. Greenwood, *Chronology of Books and Printing* (San Francisco: Gentry, 1933).
16. P. Luckombe, *The History and Art of Printing* (London: Johnson, 1771), p. 263.
17. A. P. Manutius, *Institutionum Grammaticarum Libri Quatuor* (Venice: Aldine, 1523), p. 169.
18. *Ibid.*, p. 2.
19. *A New English Dictionary . . .*, p. 504.
20. A. Hume, *Of the Orthographie and Congruitie of the Britain Tongue* (London: Trübner, 1865 [1620]), p. 23.
21. Cited in J. Burrow, *De Usu et Ratione Interpungendi* (London: Worrall and Torey, 1771), p. 25.
22. C. Cellarius, *Orthographica Latina* (Attenburgi: Richteria, 1768), p. 78 ff.
23. J. Burrow, *op. cit.*, p. 24.
24. G. Meerman, *Origines Typographicae* (The Hague: van Daalen, 1765), p. 77.
25. *Ibid.*, p. 116.
26. H. Melo, *Elucidações Sôbre o Hifen* (Fortaleza, 1960), p. 7.
27. See A. Flocon, *op. cit.*, p. 430.
28. T. B. Reed, *A History of the Old English Letter Foundries* (London: Faber, 1952), p. 38.
29. J. Moxon, *Mechanick Exercises* (ed. by H. Davis and H. Carter) (London: Oxford, 1958), p. 382.
30. P. Simpson, *op. cit.*, chap. 3.
31. Iamblichus, *De Mysteriis Aegyptiorum, Chaldaeorum, Assyriorum*, (Venice: Aldine, 1497), leaf Lv (unnumbered).
32. A. P. Manutius, *Rudimenta Grammatices Latinae Lingue* (Venice: Aldine, 1501).
33. Plutarch, *Plutarchi Opuscula. LXXXII*. (Venice: Aldine, 1509).
34. D. Erasmus, *De Recta Latini Graecique Sermonis Pronunciationes* (Venice: M. Sessa, 1531).
35. Strozius and Strozius, *Strozii Poetae, Pater et Filius* (ed. by A. P. Manutius) (Paris: de Colines, 1530).

# Automated Reading of the Printed Page

Donald E. Troxel

This paper is primarily concerned with the automated reading of the printed page resulting in a sequence of character codes which can be further processed to make the information available to a blind person in the form of Grade II Braille, spelled speech, or synthesized speech. Heuristics are described for automatic threshold determination, font-size determination, line and character acquisition, contour tracing, and the recognition of punctuation and characters. As the output of the reading machine for the blind is to be absorbed directly by a human, the specifications for a page reader were that the speed should be approximately equal to normal speaking rates and that the reader should make somewhat fewer mistakes than a human reader would make. The actual speed achieved was approximately 75 words per minute, which does not quite meet the speed requirement. However, the error rate specification has been met with a measured error rate of .07 per cent.

A number of researchers have been concerned with the problem of sensory aids for the blind. There have been numerous studies of obvious auxiliary sensory inputs such as audition and taction, and even studies of the potential usefulness of electrotactile, kinesthetic, and olfactory stimulation. At another extreme there has been a substantial effort expended with the goal of alleviating specific problems of the blind—particularly those of mobility and reading.

Work on mobility has centered largely on the development of radar-like devices to sense information which would enhance mobility. Relatively little effort has been expended on the preprocessing of this information and its presentation to the blind.

The work concerned with reading aids has been distributed more evenly across the various facets of the total problem. It has included the optophone which accesses print via a small vertical slit, leaving the blind with a very complex recognition problem; a direct translation aid developed by Bliss and Linvill<sup>1</sup> which presents an enlarged virtual tactile image of the print; a small, relatively low performance

character recognition machine developed by Mauch Laboratories<sup>2</sup> which utilizes spelled speech as its output; and a moderately complex page reader developed at M.I.T. which can communicate with the blind via spelled speech, Braille, or synthesized speech.

The earliest version of the M.I.T. system was first demonstrated in the spring of 1966. It was then capable of reading a single line of text, recognizing the characters and punctuation, and spelling out these symbols aurally. This experimental system was not intended to be a prototype of a practical reading aid but rather was a real-time research facility for the experimental investigation of human information requirements and human learning capabilities upon which prototype designs must be based. This experimental system has facilitated research on print scanning, character recognition, control by a blind reader, and auditory displays.<sup>3,4,5,6,7</sup>

One of the crudest features of the initial reading machine system was the opaque scanner, and work commenced immediately to develop an improved scanner and carriage control which would handle whole pages of print rather than individual lines. During the spring of 1968, funds were made available for the purchase of a PDP-9 computer which was to be used primarily for reading machine development. This computer has formed the nucleus of a second research version of a reading machine for the blind which, while still not a prototype, has considerably improved capabilities and represents a significant step towards the eventual realization of a practical machine.

### *System Description*

The system diagram for the second version of the reading machine is shown in Figure 1. The transformation of a printed page into Braille, spelled speech, or synthesized speech has been demonstrated with this system.

The printed pages used thus far have been removed from a fourth grade reader entitled *Roads to Everywhere* published by Ginn and Co., Boston, 1964, and printed in 14-point Textype type. Only those pages have been used which do not contain pictures.

The opaque scanner is a flying spot scanner in which a dot of light positioned on the face of the cathode ray tube (CRT) is imaged on the page. The total light reflected from the page is sensed by photo-

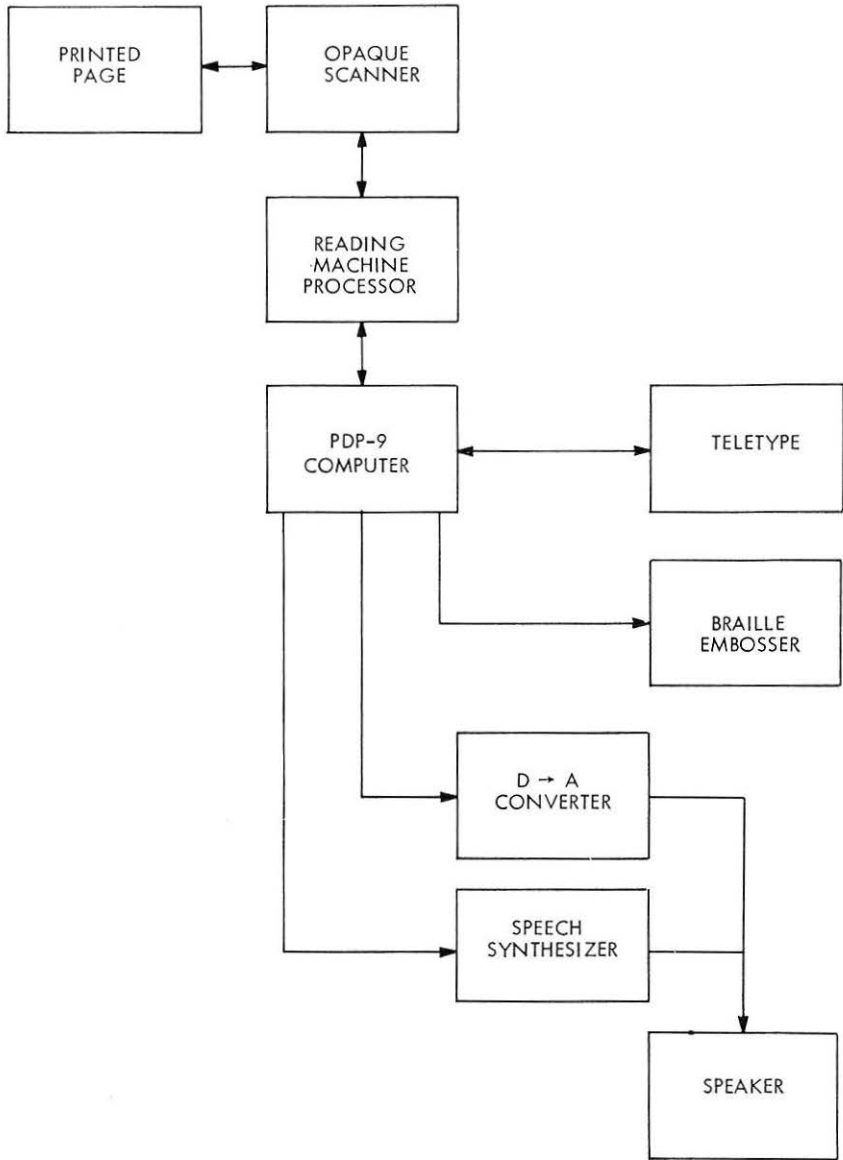


Figure 1. Reading machine system diagram.

multiplier tubes, the output of which is a function of the whiteness of the particular spot on the page. To achieve high resolution, the face of the CRT is imaged on to approximately one square inch of the page. The minimum necessary resolution has not yet been determined. Access to the whole area of the page is provided by a carriage which is integral to the opaque scanner and permits both horizontal and vertical motion of the page. Both the carriage and opaque scanner are operated by the reading machine processor (RMP) which in turn receives directives from the computer. This RMP in effect extends the instruction set of the computer and allows various complex functions to be initiated by the computer and to be performed while the computer is engaged in other calculations. One such directive which is often used is, "Given that the dot of light on the CRT is imaged on the contour of a character, find the next sequential contour point and return its coordinates to the computer." It was deemed necessary to provide these functions in the hardware rather than to perform them by computer program so that recognition rates could approximate human speaking rates.

The recognition of alphanumeric characters is a modification and extension of procedures developed by Clemens,<sup>8</sup> where a number or signature is computed from the exterior contour of a character, and the character is "recognized" by finding a match in a previously generated table of signatures and character codes. The sequence of operation of the page reading programs is indicated in Figure 2. The first step is page initialization where the threshold for the discrimination of black and white on the page is computed. The size of the typeface on the page is determined, and the left and upper boundaries of print on the page are located. Starting from the top of the page, the first line of print is acquired, and then the first character in this line is acquired. Then the exterior contour of the letter is traced; and if the character is deemed large enough, a signature is computed and the signature table is searched to yield the code for the character. Then an attempt is made to acquire the next character. Eventually all of the characters on that line will be processed and no such character will be available, resulting in an end-of-line determination. When this occurs, the program attempts to acquire the next line of print. If no such line is found, then the page is deemed finished.

If, after a character has been traced, it has been deemed small

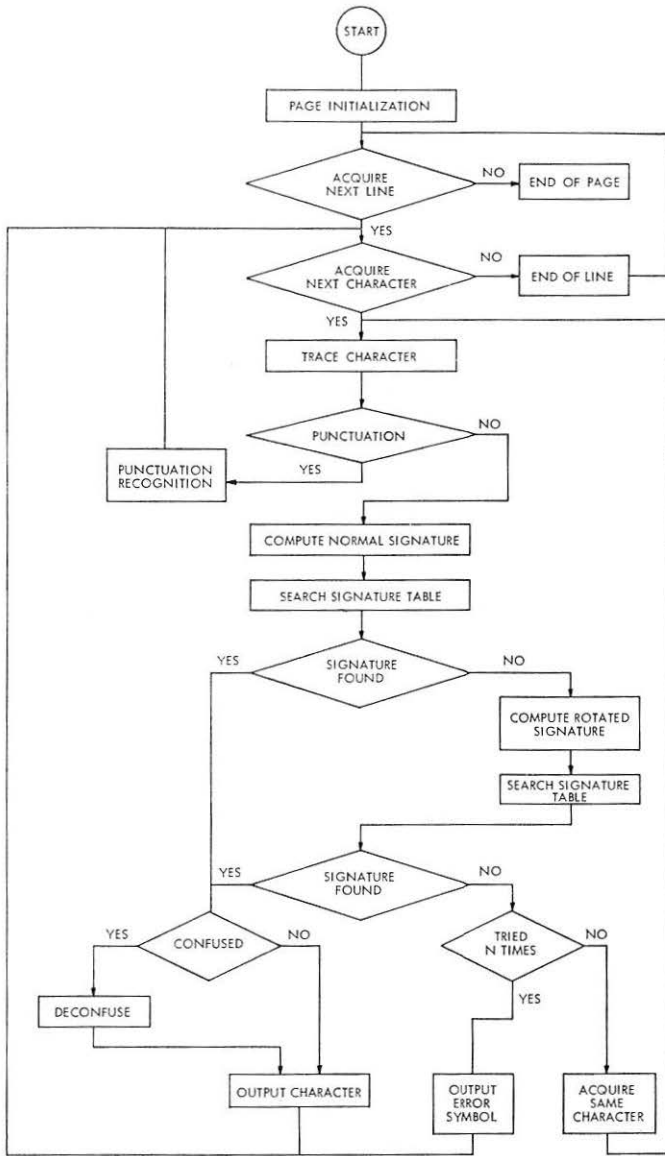


Figure 2. Page reader flow chart.

enough to be punctuation, control is transferred to a special routine which recognizes the punctuation mark and proceeds to acquire the next character.

As seen in the lower portion of Figure 2, it is possible that the first signature which has been computed is absent from the table. In this case an alternative method of computing the signature is used and the table is searched again. When a signature has been found in the table, it may or may not represent a unique recognition. This results from the fact that some shapes which correspond to two different characters result in the generation of identical signatures. Fortunately there are not very many occurrences of these confused signatures, and it has been possible to resolve these confusions by making auxiliary tests. If both signatures just generated do not exist in this signature table, then the character is reacquired and traced again. This procedure of trying again is applicable because it is an experimental fact that the statistics of signatures generated by successive tracings of the same character are similar to the statistics of signatures generated by successive tracings of like characters.

#### *Page Initialization*

Page initialization performs three main functions: the determination of an acceptable threshold for subsequent black-white decisions, the determination of the size of the typeface existing on the page, and the positioning of the carriage for subsequent acquisition of text. As the scanner can only access approximately one square inch of the page area, it is first necessary to locate the carriage so that this aperture contains some print. In the present system, this is accomplished simply by moving the aperture to the center of the page; then a number of A to D conversions are made over this central portion of the page, and the threshold is computed from a histogram of the results of these A to D conversions, as indicated in Figure 3. The two peaks of this histogram corresponding to the most common black and the most common white are found. Then the minimum of the central region of the histogram as bounded by these peaks, is determined. The threshold is then computed as the mid-point of a horizontal line drawn a fixed distance above this minimum and bounded by the interior sections of the histogram.

The font size is characterized by the x-height, which is the height of

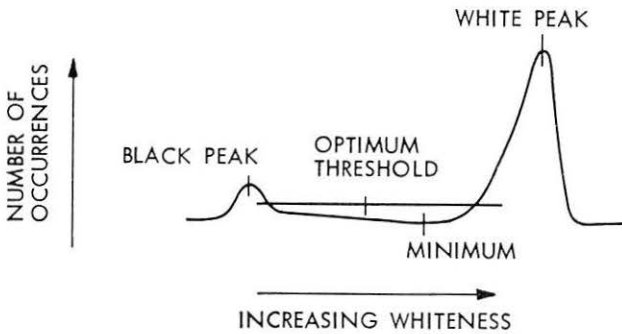
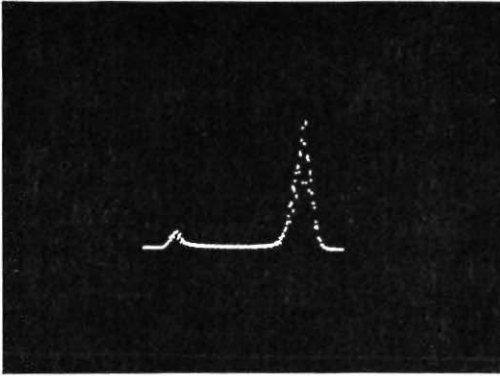


Figure 3.  
Threshold  
determination.

the lower-case x. This x-height is determined by tracing the contours of a number of characters and is calculated as the average height of the smallest characters, provided that there exists one character which is substantially taller than the smallest character. Care is taken, of course, that specks do not find themselves classified as characters.

The left print boundary is determined by moving the carriage so that the left edge of the aperture is guaranteed to be black (i.e., off the page). Then the aperture is moved right until a substantially all-white area is found. The motion to the right is continued until a substantial amount of black (the left edge of the print) is found. The aperture is then moved so that the print boundary is near the left edge of the aperture and the accuracy of this move is checked.

The top print boundary is found in a similar manner, but the top line of print is positioned in the center of the aperture.

### *Line Acquisition*

Line acquisition makes extensive use of the horizontal histogram (HH) directive which is issued by the computer and executed by the RMP. When this directive is initiated, the RMP interrogates all points at a specified y value within the aperture and returns the total number of black points encountered. The heuristic used for the acquisition of a line involves the execution of the HH at selected y values. At first the search is coarse, that is, with a significant space between successive y values. When the number of black points encountered is greater than a fixed constant for four successive lines, the HH is executed every fourth y line (Fig. 4A); and the maximum number of black points is computed. When the number of black points resulting from a HH is less than one-eighth of the maximum encountered thus far, the base line of the line of text has been passed; and a fine search is performed but for increasing values of y until the number of black points is greater than one-half of the maximum previously encountered (Fig. 4B). Since this heuristic has been implemented, there has not been even a single instance of failure in the determination of the base line of a line of text, whether or not it contains letters with descenders.

For second and subsequent lines, the motion of the aperture of the scanner is effected to place the next line approximately in the center of the aperture, as well as returning the aperture to the left edge of the print. An end-of-page determination is made if no line can be found within the scanner aperture.

### *Character Acquisition*

Character acquisition again makes use of another directive executed by the RMP. In this directive, a vertical scan is performed between two y values starting at a particular x value. If a black point is not encountered, the vertical scan is performed again but indexed to the right in x. This continues until a black point is encountered or the value of x equals that of the x mask. This scan is indicated in Figure 5. The values of the upper and lower y limits, the starting value of x and the x mask are transmitted to the RMP prior to the execution of the acquisition scan. Before the acquisition scan is initiated, the aperture is moved if necessary. The x mask is positioned so as to guarantee that if a character is found before reaching the x mask the character will be fully within the scanner aperture. The contour of the character is then

Figure 4. Line acquisition.

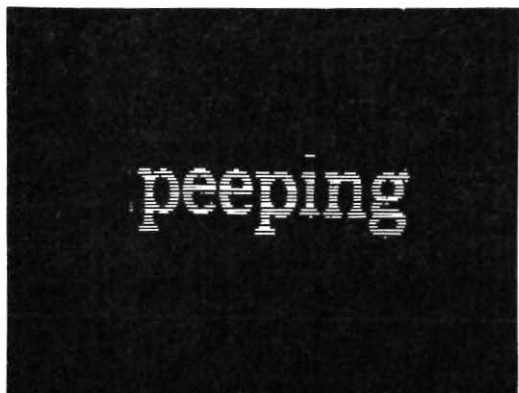


Figure 4a. Search every fourth line.

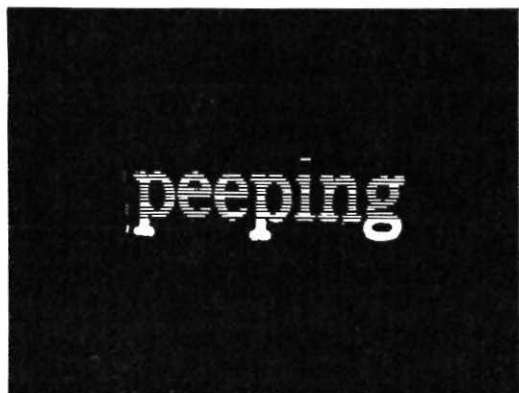
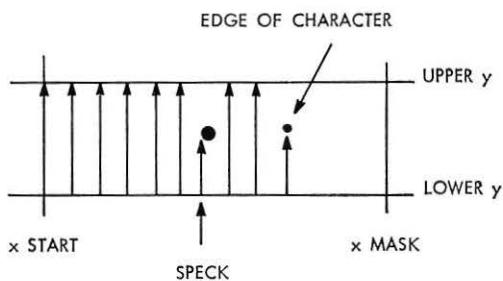
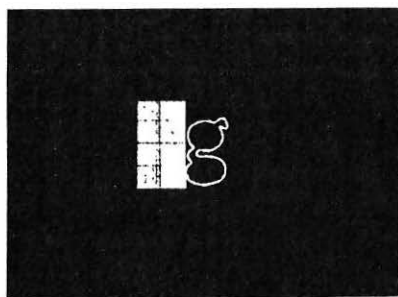


Figure 4b. Addition of fine search upward.

Figure 5. Acquisition scan.



traced. If the number of contour points is smaller than a fixed constant, it is deemed a speck; and the acquisition scan is restarted to the right of that speck. When large specks are encountered they are sometimes "recognized" as periods. The end-of-line determination is made if the acquisition scan has proceeded for a certain value of  $x$  with no more than specks being found. When the first character of a line has been found, the left edge of this character is compared to the left edge of the print on the page to see if a paragraph has been encountered. For succeeding characters, the distance between the left edge of the newly acquired character and the right edge of the previously acquired character is used to determine whether or not a space or spaces should be transmitted.

### *Contour Tracing*

The fact that the exterior contour of a letter is traced has often been considered a key feature of the character recognition algorithm used. However, contour tracing has little to do with the character recognition algorithm, as it is primarily a means of defining the precise location of the character to be recognized. It is, however, a relatively fast technique for extracting the useful information from a fairly large area if one is confined to an optical transducer which can test only a single point at a time. A character in a  $50 \times 100$  grid would require 5,000 tests if every point on the grid were to be examined. However, it would have only about 300 edge points, which would require approximately 600 tests.

There are many ways in which contour tracing can be implemented.<sup>5</sup> Perhaps the simplest digital method is the square trace (see Figure 6) which can be described by the following rule: If the last point tested was black (white), then make a  $90^\circ$  left (right) turn to determine which point will be tested next. This contour trace algorithm works well on fixed data. As a matter of choice, the points which are interrogated are along the edges of a letter. These, of course, are the very points which are on the borderline of being black or white. If there is even a small amount of noise present in the optical scanner, successive interrogations of the same point are likely to reveal different answers.

Because of the square trace algorithm's propensity to test the same point twice, it is possible to become trapped in black or white. A

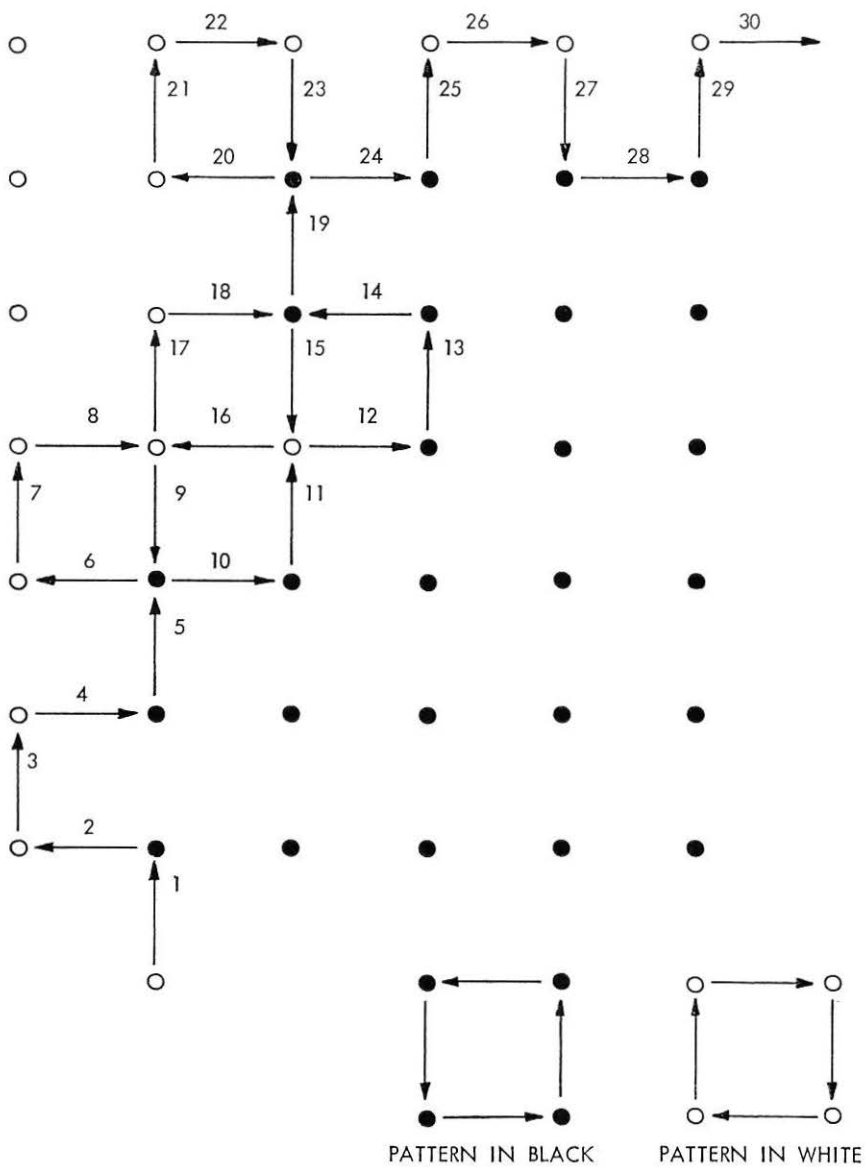


Figure 6. Square trace.

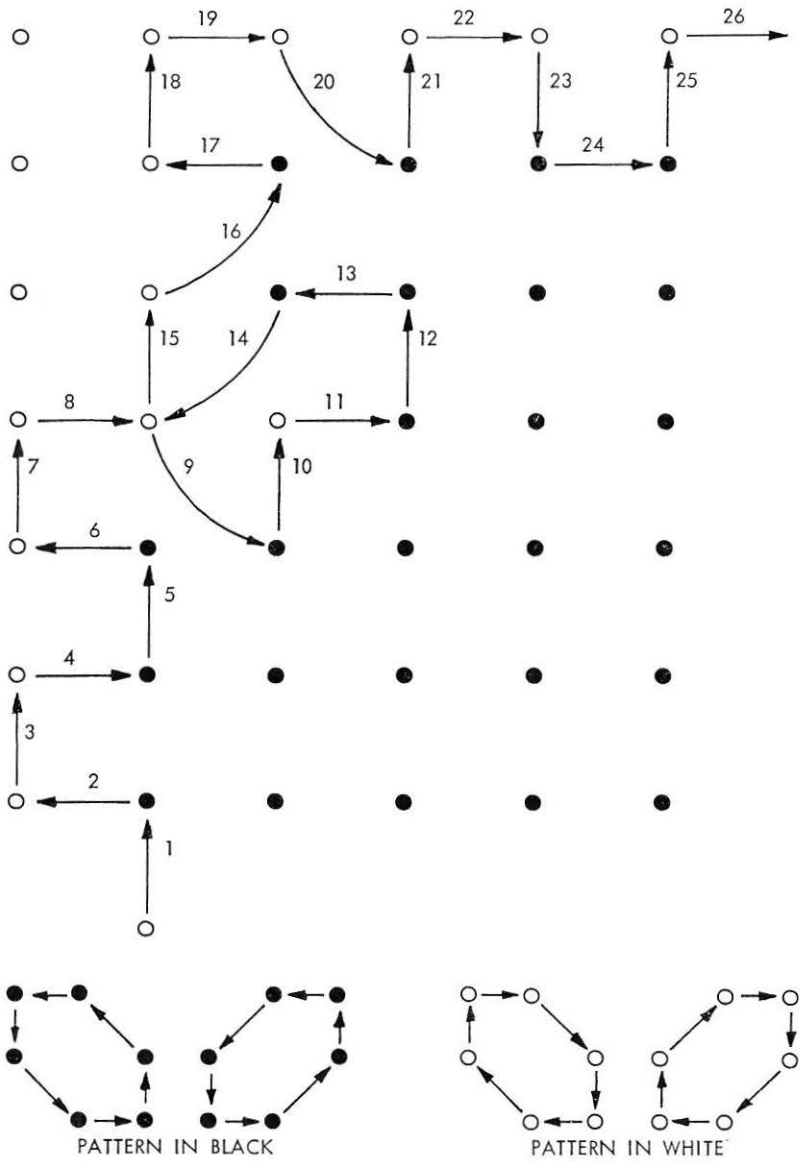


Figure 7. Modified square trace.

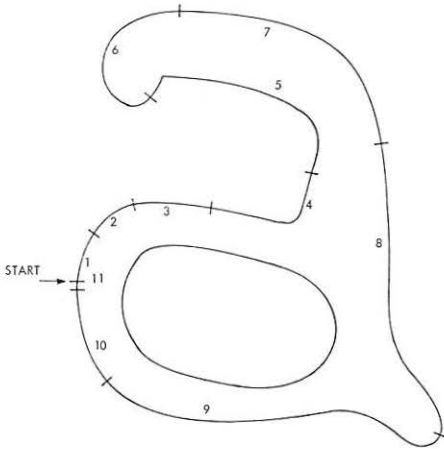


Figure 8.  
Segmented  
contour trace.

variation of the square trace algorithm, which is shown in Figure 7, eliminates the possibility of becoming trapped in black or white when the spatial quantization and grayness of the letter edges are such that the picture elements which are on the borderline between being black or white are less than two coordinate units wide. In general, this variation minimizes the square trace algorithm's tendency to test the same point twice by forcing diagonal moves when the three previous points were either all white or all black.

As is indicated in Figure 7, it is possible to become trapped in black or white even when using the second algorithm. The trapped condition is detected by the occurrence of six successive black (white) points and is termed a contour trace error. As the contour trace algorithm is realized in hardware by the RMP, the contour trace subroutine merely has to ask for the next contour point. Of course, the subroutine must determine when to terminate the tracing of a character. This is accomplished by a distance calculation of the present contour point relative to the initial contour point. The distance measure used is the maximum of the magnitude of the displacement in x or y. To minimize the time taken for the contour trace, this distance calculation is made only as often as is necessary to be sure that the original contour point has not been bypassed. Thus, the contour of a character is traced in segments as indicated in Figure 8, where the length of the perimeter of the next segment is determined by the distance measure of the present contour point to the initial contour

point. Each time the distance calculation is made, a check is also performed to see if any contour trace errors have occurred on the previous segment; and if such is the case, the contour trace is restarted at the end of the previous segment. The shape whose contour has been traced is deemed a speck if the number of contour points is below a fixed threshold or if the initial distance calculation is less than a constant.

### *Punctuation Recognition*

If the number of contour points of the shape as traced by the contour trace routine is smaller than a constant, then the character is considered to be a punctuation mark. Of course, this constant could easily be computed as a function of the typeface size. The allowable punctuation alphabet is shown in Figure 9, which also indicates the sequence of decisions which are performed.

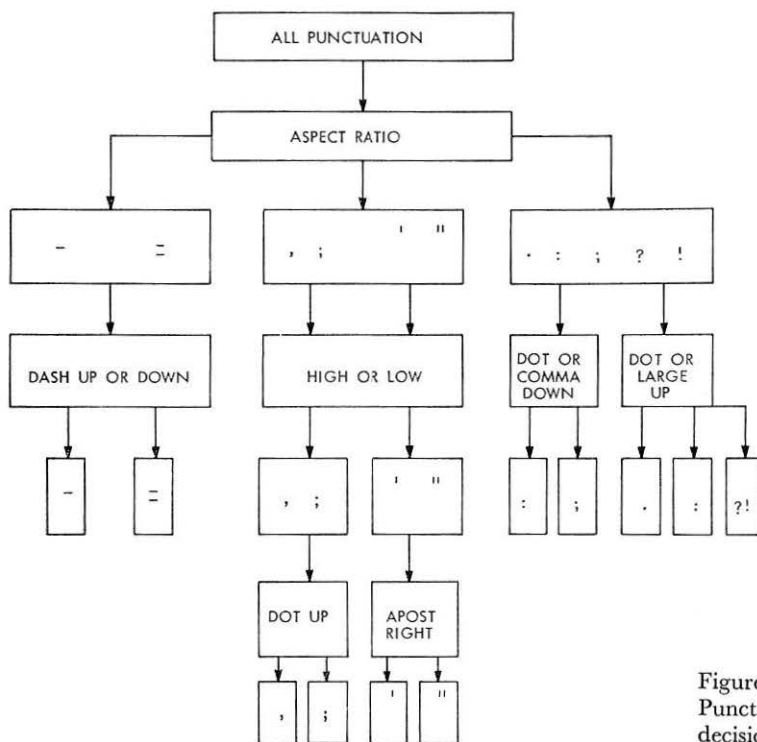


Figure 9.  
Punctuation  
decision tree.

The first decision is based upon the aspect ratio of the rectangle circumscribing the shape and divides it into three classes. A further discrimination between a dash and an equal sign is made by searching areas just above and below the shape for the existence of another dash-like character. It is conceivable that a shape which is not dash-like in its aspect ratio could be found, and this would be interpreted as an error. Those punctuation marks with the largest aspect ratios are further subdivided by their vertical position into two more classes, and these classes are resolved by searching appropriate areas for possible additional pieces of the punctuation mark. Punctuation marks which have aspect ratios near unity are similarly further classified by appropriate searches above and below the shape. The existence of a large shape above a dot is taken to indicate the presence of a question or exclamation mark, and these larger shapes are treated in exactly the same manner as alphanumeric characters.

### *Character Recognition*

The basic scheme for character recognition is a modification and extension of the one that was used in the first M.I.T. reading machine system and is described in detail by Clemens<sup>8</sup> and Seitz.<sup>5</sup> After the contour of a letter has been traced, a characteristic number or signature is generated and a table of previously encountered signatures is searched for a match. The signature is computed by the method indicated in Figure 10.

As previously noted, there are two methods used to generate signatures—normal and rotated. In the normal case the signature is a concatenation of a code word and a coordinate word. For the rotated signature the same code word is used but the coordinate word is replaced by a rotated code word.

The code word is computed by finding local extrema for the horizontal and vertical directions if the excursions along the contour are greater than one-quarter of the letter height or width. That is, for example, an x maximum is not denoted unless one had to travel east for at least one-quarter of the letter width and then west for one-quarter of the letter width. With this scheme, minor features of the letter such as the droop in the upper left part of the “a” do not introduce extraneous extrema. The sequence of extrema can be coded with one bit per extremum if the first extremum recorded is an x minimum



and the contour trace is clockwise. The coordinate word is made up of a sequence of bit pairs specifying the quadrant in which a horizontal or vertical local extremum occurred. The rotated code word is computed in the same manner as the normal code word except that local extrema are determined with respect to x and y axes rotated by 45 degrees. These binary sequences, along with a small amount of information concerning the aspect ratio of the letter and its position relative to the y lines found by the line acquisition procedure, comprise the signature.

In order for characters to be recognized, the particular signature must have been encountered previously; that is, the machine must have been previously trained by a sighted operator. To enable the sighted operator to recognize the letters, a visual display (Fig. 11) is made. When the machine is unsuccessful in the search for a match for a particular signature, it can ask the trainer what the character is. Given this information, it can thus add to its experience. There is a certain amount of noise involved in the determination of black and white, and the presence of this noise actually simplifies the training procedure, as it appears that successive tracings of the same "a" have variations similar to tracings of different "a's." Thus a character repeat mode is provided in which one can lock on to a particular letter and build a repertoire of signatures for that particular letter.

### *Multiple Font Recognition*

There are three aspects of the page reader programs which are peculiar to a specific font. These are the signature table, and the punctuation and deconfusion routines. Separate signature tables for any desired font can be generated easily by use of the training mode. The deconfusion routines which may be required must be programmed to resolve confusions generated during the training process. Punctuation recognition routines are probably quite universal as punctuation marks have small variations among most fonts. No provision has yet been made for truly multiple font recognition, i.e., when a single page contains a mixture of fonts.

### *Performance*

Ten successive readings of the same page were made in order to test the accuracy of the page reading process. The page read consisted of

1087 characters, including letters, punctuation, spaces between words, end-of-line determinations, paragraph determinations, and an end-of-page determination. A total of twelve errors were made for a gross error rate of approximately 0.11 per cent. Four of the errors dealt with spaces, either missing or added. A program “bug” has been found and corrected so that this type of error no longer occurs. Two punctuation errors occurred in which a single quote was substituted for a double quote. There were four letter substitution errors and two letters not recognized. Virtually all of the mistakes concerned with letters were the result of broken or touching letters. If we discount the space related errors, the error rate was approximately 0.07 per cent. People are normally accustomed to reading text with considerably higher error rates.

The speed attained by the page reader is adequate for Braille or spelled speech output. It is, however, somewhat marginal for synthesized speech output. The average speed is 75.5 wpm. A large amount of the time spent in reading is “wasted” while the computer is awaiting completion of carriage motions. If we subtract the time spent waiting for completion of carriage motions, the reading speed would be 119 wpm.

### *Typeface Design*

The following characteristics of typefaces are desirable to minimize the complexity of character recognition procedures as well as to facilitate both lower error rates and higher recognition speeds. While the reliability of optical character recognition machines can be enhanced by special type styles, the type designer should not be expected to go to the extremes required by the magnetic characters on bank checks or OCR-A (Fig. 12).

ABCDEFGHIJKLMN O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0 - = ■ ; ' , . /

¥ ¢ £ ¤ % | & \* + □ ■ — { } ¤ : " ?

Figure 12. OCR-A.

Virtually all print reading machines must represent the image of each character as a two-dimensional array of black and white dots. The required resolution or number of picture elements (dots) per inch is a function of both the minimum stroke width of a character and the minimum distance between strokes (or between serifs). Higher resolution is expensive both in cost of the optical scanner and in processing or recognition time. In addition, some machines are sensitive to variations in stroke width, so it is desirable for a typeface to have a stroke width which is uniform (consistent with aesthetic considerations) and is wider than some minimum, such as approximately 1/50 inch. It is equally important that the minimum distance between strokes or between serifs be at least as great as the minimum stroke width. This minimum separation distance becomes critical between adjacent letters. Ligatures are acceptable as they can be treated as an additional character. Consistency is the key—if a letter pair always touches, it can be handled even though the complexity of the recognition procedure is increased slightly. Letter pairs that *sometimes* touch cause complications.

Another desirable characteristic is that characters be distinctly different. This statement may sound rather silly, but it is not uncommon for zero and capital Oh to be similar or for one and lower-case l to be identical. And it is desirable that this quality of distinctness be independent of vertical position. Common offenders in this regard are 9 and lower-case g, upper-case P and lower-case p, and upper-case Y and lower-case y. Virtually all automatic readers process each character separately and do not make use of contextual information as do human readers. Distinctness independent of vertical position facilitates the task of reading skewed lines or unevenly spaced characters.

Most type styles designed expressly for automatic reading are sans-serif. This is not in itself a desirable goal, but it does make it easier to adhere to stroke width and character separation specifications.

1. J. G. Linvill and J. C. Bliss, "A Direct Translation Reading Aid for the Blind," *Proc. IEEE*, 54 (1) (January 1966), 40-51.

2. G. C. Smith and H. A. Mauch, "Summary Report on the Development of a Reading Machine for the Blind," Mauch Laboratories, Inc., Dayton, Ohio, VA

Contract No. V1005M-1943 (June 1968). See also: G. C. Smith, "Type Reading Machines for the Blind," *The Journal of Typographic Research*, II (April 1968), 107-125.

3. D. E. Troxel, F. F. Lee, and S. J. Mason, "A Reading Machine for the Blind," QPR No. 89, RLE, M.I.T.

4. D. E. Troxel, F. F. Lee, and S. J. Mason, "A Reading Machine for the Blind," *Digest of the 7th International Conference on Medical and Biological Engineering*, 1967. Stockholm.

5. C. L. Seitz, *An Opaque Scanner for Reading Machine Research*, SM Thesis, M.I.T., 1967.

6. D. E. Troxel, "Page Position Selection for Use with a Reading Machine for the Blind," *Digest of the 8th Annual IEEE Symposium on Human Factors in Electronics*, 1967, Palo Alto.

7. D. E. Troxel and G. F. Pfister, "Optimum Threshold Level for the Reading Machine Opaque Scanner," QPR No. 86, RLE, M.I.T.

8. J. K. Clemens, *Optical Character Recognition for Reading Machine Applications*, Doctoral Thesis, M.I.T., 1965.

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*Cover Illustration: The Duke Parchment Palimpsest Fragment*

According to Dr. William H. Willis, professor of Greek at Duke University and president of the American Society of Payrologists, the Duke Plato (*PKuk*. inv. G5) is significant in three respects: (1) it is the first example of a Plato text on parchment, (2) it is the earliest known Plato in codex form, rather than in a papyrus roll, and (3) it is the first known application of Roman uncial to parchment. It takes its place among only four surviving examples of first- or second-century parchment codices—bound books invented in Rome in the late first century.

It was close examination of the writing that convinced Dr. Willis that the parchment might be a rarity. Not an entire word was visible to the naked eye, but there was evidence of Greek uncial writing which was reserved for the most important texts in the most elegant editions. Ultra-violet light made visible the lines of the original uncial work by tracing the grooves etched by the writer's pen on both sides of the skin. Comparison of its "hand" showed it to be almost exactly like those in a papyrus roll containing part of the Iliad which came to light in 1888 with the mummy of a Graeco-Egyptian lady whose entombment is known to have been in the second century. The same hand is in another Homer papyrus at Oxford, which also is assigned a date in the early second century. And there are more than a dozen well-documented papyrus rolls written in Roman uncial, all datable to the first or second century, none of them later.

"In the history of manuscripts it is the period preceding the fourth century which remains essentially uncharted," Dr. Willis states, and it is on this early development that the Duke Plato throws light.

# Vocalism in Silent Reading

Donald L. Cleland

A continuing controversy has been going on as to whether vocalism in silent reading should be inhibited, encouraged, or just tolerated as part of the reading process. Past experimentation is discussed. Reported here is an investigation to determine the incidence of vocalism during silent reading by two groups of intermediate grade children: reading achievers and reading retardates. A general conclusion is that vocalism is a natural adjunct of the reading process and that at appropriate times all of us use it as a secondary sensory reinforcement.

Many aspects of the art of teaching language skills have remained a controversy over a period that encompasses public education in our democracy. Among these is the topic of vocalism. The fact that it has many synonyms, certainly, has not cleared the education air; but on the contrary has, perhaps, added to the confusion. A search of the literature would reveal such synonyms as implicit speech, inner speech, covert language, inner vocalization, sub-vocalization, silent speech, and vocalism.

The fact that controversy exists, that some say it is part and parcel of the reading process, and others say that techniques should be employed to inhibit its existence, is ample reason that concerted attempts should be made to resolve the problem.

Early judgments concerning the role vocalism plays in the reading process were based on introspection. Two diametrically opposed views may be represented by S. S. Stricker (24) and M. Paulhan (22) who gave their considered opinions during the latter part of the nineteenth century. Stricker and his subjects assert that they could not think of letters or words without experiencing allied speech-motor phenomena. On the other hand Paulhan claimed that he could think of anything without experiencing the corresponding speech-motor phenomena. Bain (3) a physiological psychologist considered thinking

to be more or less restrained vocalization or acting. Egger (12) and Ballet (4), French psychologists investigating aphasia, announced, "To read as a matter of fact is to translate the written word into words to be spoken."

Believing that inner speech may be a detriment to efficient silent reading, O'Brien (21), McDade (19), and Buswell (5) suggested a non-oral method of reading instruction. The results were somewhat inclusive and discouraging. The non-oral method did not eliminate silent speech to any greater degree than did other methods.

Anderson and Dearborn (2) and endorsed by Tinker (26) made a rather revolutionary recommendation that vocalism is a desirable, developmental, learning reinforcement activity, and that its elimination should not be prematurely precipitated. Of interest, at this juncture, is Hollingsworth's (16) theory of cue-reduction or redintegration in which a portion of a complex stimulus would elicit the same response as the original complex stimulus would evoke.

Early attempts at measuring vocalism were crude but rather ingenuous when consideration is given to the methods and equipment available. Curtis (9) placed a tambour on the larynx and recorded its movements while the subjects read "Hiawatha"—silent reading produced more movements than any other mental activity. Only actual whispering produced more. It is interesting to note that four of the experimental cases manifested no movement at all. Parallel to Curtis' work are the results obtained by Courten (8) by obtaining movements of the tongue during the performance of the same activities as Curtis' experimentees. Courten worked with a rubber bulb on the tongue, the bulb being connected to a recording tambour.

Probably the first experiments in which needle electrodes were used to obtain records of muscular action potentials (MAP) from the speech musculature were performed by Jacobson (17) during the early part of the nineteenth century. The electrodes of fine platinum iridium wires, were inserted into the muscles of the tongue or lower lip. The testees in these experiments were instructed to imagine counting from one upward, to imagine telling something to a friend, or think of abstract subjects such as "democracy," "eternity," "electrical resistance," and "Ohm's law," or the meaning of the words such as "incongruous" or "everlasting." The subjects were trained in differential relaxation or the ability to consciously relax individual muscles or groups of muscles.

The recordings of the muscles of the tongue or lower lip of these testees as measured by a galvanometer indicated very nearly no activity when the relaxation was called for, but as soon as a signal was given to perform the tasks listed previously, electrical activity was noted.

Of interest in this connection, also, is the work of Max (18). Surface electrode recordings were obtained from muscles of the arms of 18 deaf mutes, as "the arms and fingers of this group of individuals are the focus of their oral, written, and gestural speech." Comparisons were made with a group of 16 persons with normal speech abilities. The testees were instructed to perform tasks similar to those of Jacobson's study above. In 31% of the control group, muscular activity was noted while in the experimental group, muscular activity was noted in 86% of the cases.

Another study, which certainly is of value to the topic under discussion, was done by Faaborg-Anderson (13) on the functioning of the intrinsic laryngeal muscles in humans. The aim of this study was to determine the degree of activity of these muscles as active in the process of speech, both in the case of healthy persons and in the case of patients with paresis of the vocal cords. Silent speech was accompanied by an increase in electrical activity and action potential of the laryngeal muscles of both groups.

From the above studies it can be concluded with confidence that an increase in electric activity (action potential) in the speech musculature occurs during certain types of mental activity. A question may be posed at this point: "Would there be an increase in muscle action potential (MAP), which can be called a manifestation of silent speech or vocalism, during the process of silent reading?"

The publication, *Silent Speech and Silent Reading* by Ake W. Edfelt, (1960), director of reading research at the University of Stockholm, revealed the only comprehensive, adequately instrumented, and controlled study of implicit speech. In this classical book, Edfelt describes his method of recording implicit speech by a technique called electromyography, the literal meaning of which is electric writing of the muscles. It is premised on the fact that a muscle has a certain electric potential, i.e., a minute electric charge and that this charge will increase as muscles contract. This electric action potential can be measured by either surface electrodes appropriately placed on the

skin or needle electrodes which are placed inside the muscle. General investigators Adrian and Bronk (1) have shown that these electric potentials increase in number as well as frequency when muscular contraction increases.

Edfelt (11), in connection with the reception of new students at the University of Stockholm, gave a series of lectures on the possibilities for bettering a poor ability in reading. An invitation was given to those who wished a further check-up, and, possibly needed advice concerning improvement. Of the 600 new students who attended the lectures, 160 indicated an interest in the program as outlined, and of these 84 were finally selected for the experiment. The investigation of the students who participated included an intelligence test, and the assessment of reading ability by a test in reading speed, a test in reading comprehension and a vocabulary test. Of special interest, however, was that reading comprehension was assessed by means of open-end questions, instead of the more conventional multiple-choice type. Finally three groups of readers were selected: good, medium, and poor. Medium readers were defined as those whose scores fell with plus or minus .5 above and below the mean. Good and poor readers were defined as those who scored above +.5 and below —.5 of the mean.

The students were tested in a Faraday enclosure, reading easy then hard, and clear then blurred material. Benzocaine lozenges were used as a topical anesthetic in preparation of placing needle electrodes in the mylohyoid muscle of the tongue. The results of the experiment may be summed up as follows:

1. Good readers engage in less silent speech than do poor readers.
2. The reading of an easy text results in less silent speech than does the reading of a difficult one.
3. The reading of a clear text results in less silent speech than does the reading of a blurred one.

Implicit in the above is that silent speech occurs in different amounts in all reading. Edfelt has drawn some interesting conclusions from his study; yet these results clearly seem to prove that silent speech cannot have a detrimental effect on reading performance. "Already . . . it was pointed out, as well, that nothing is known concerning reading without silent speech. If these facts are united, it

seems clear that the advisability of direct attempts to eliminate silent speech is highly dubious.

A three-year study conducted by the University of Pittsburgh at the Leech Farm Veterans Hospital and sponsored by the United States Office of Education, Contract No. OE 4-10-056, has yielded some interesting data.

The main purpose of the investigation was to determine the incidence of vocalism during silent reading of two groups of intermediate grade children, i.e., one group which may be classified as reading achievers, and a second group classified as reading retardates. A secondary purpose was to relate methods of beginning instruction (basal vs. basal with supplementary phonics) to the incidence of vocalism during silent reading. Vocalism in this instance is the implicit muscular movements of the musculature of the lips as measured by muscle action potentials (defined elsewhere in this paper). In this investigation, vocalism in silent reading will be measured by counting the output epochs of an electric integrator which transforms the amplified muscle action potentials of the musculature of the lips to oscillographic writing. The main difference between Edfelt's procedure and the one employed by the University of Pittsburgh is that the lip action potentials were picked up by disc electrodes and amplified by a Grass, 10 channel electro-encephalographic recording instrument. The Grass Integrator was used to facilitate the interpretation of the myographic output. Essentially, the integrator is an electrical capacitor or condenser which is connected across the two leads to the ink writing pens. Electrical energy is, therefore, stored in the capacitor. As its peak of capacity is reached, the ink-writing pen gradually deflects, and when the peak has been reached, it discharges and the ink-writing pen returns quickly to its zero position. The gradual deflection (rising) of the ink-writing pen and its sudden return to the zero position constitutes an epoch. The incidence of vocalism can, therefore, be determined by counting the number of epochs over a designated period of time.

The specific elements of the problem are as follows:

1. To determine the incidence of vocalism in silent reading among a selected group of intermediate-grade children.
2. To determine which of two groups of these children has the higher incidence of vocalism in silent reading.

3. To determine the relationship, if any, between the incidence of vocalism in silent reading and reading rate.
4. To determine the correlational relationship between the efficiency of comprehension during silent reading.
5. To determine the correlational relationship between the methods of reading instruction (Basal Approach vs. Basal with Supplementary Phonics) and vocalism in silent reading.
6. To determine the correlational relationship between selected reading and language processes, such as oral reading skills, spelling skills, listening skills, etc., and vocalism in silent reading.
7. To determine, if possible, at which rate of reading there is the minimal incidence of vocalism in silent reading.
8. To determine by which mode of presentation of reading materials (mechanical or non-mechanical) there are fewer incidents of vocalism in silent reading.

A population of 211 intermediate grade children were selected from a total sample of approximately 1,200 students. At the outset of the study a series of five tests were administered to each of the 1,200 children. These tests were:

1. STEP (Sequential Tests of Educational Progress) Listening Test, Part I and Part II.
2. American School Achievement Tests, Intermediate Battery, Arithmetic Computation, Form E, Part II.
3. SRA Primary Mental Abilities Test (PMA) Grades 4-6.
4. Gates Reading Survey Test, Forms I and II.

Based on the first three tests listed above, a regression equation was employed to determine the REL (Reading Expectancy Level) of each child. This regression equation was validated in a study by Toussaint (27).

The actual reading level of each child was determined by averaging the scores obtained from the Gates Reading Survey Test, Forms I and II, each form administered on different days.

Two hundred and eleven subjects were chosen from the total population of 1200 fourth, fifth, and sixth graders. These 211 subjects were placed into one of two groups:

1. Reading Achievers—whose actual reading level was at least  $+.6$  grade level above their REL. (N=116)
2. Reading Retardates—whose actual reading level was at least  $-.6$  grade level below their REL. (N=96)

The following tests, using appropriate sub-sections, were then administered to the selected subjects:

1. The McCullough Word-Analysis Test
2. Spache Spelling Test
3. Wepman Auditory Discrimination Test—Form I
4. Gilmore Oral Reading Test—Form A
5. Stanford Binet Intelligence Scale—Form L-M

With the completion of the testing as described above, the subjects were then ready for the standardized routine of obtaining the electromyograms (EMG).

As a result of a series of preliminary experiments exploring various electrode locations and combinations, the following technique for electromyography was adopted. Three disc electrodes of the conventional electro-encephalograph type modified for attachment with flexible collodion were located around the lips. One was placed midway between the midline and the corner of the mouth approximately 1 cm. above the upper lip line. A second was placed approximately 1 cm. lateral to the corner of the lip. A third was placed midway between the midline and the corner of the mouth approximately 1 cm. below lower lip line. With the patient grounded by a similar electrode attached to an ear lobe, bipolar recordings were made from the three possible pairs of lip electrodes. Two sets of similar recordings were made as follows:

1. Raw EMG's so that, if possible, correlations could be made between EMG patterns and patterns secured through the calibrations.
2. Integrated EMG's to facilitate the quantification of MAP.

In order to assist in the later identification of particular patterns of EMG activity, it was considered desirable to "calibrate" each subject by presenting a standardized list of pictures, words and sentences. For this purpose the Bryngelson-Glaspey speech test cards were produced on 35 mm. film and a graded list of words and sentences ranging from

first to twelfth grades in difficulty were used. During the presentation of these materials, pictures and words presented visually and the sentences auditorially, a key was operated by an observer or by the projector operator so that signal marks are made on the EMG record which allows subsequent identification of the exact material presented to the subject at a time when a particular pattern of EMG activity is recorded. During this phase of the procedure, the subject also counted from one to thirty, each count on signal. This was done both silently and orally.

Following the preliminary "calibration" procedures, reading material was presented mechanically and non-mechanically. Mechanical presentation was by means of a metronoscope, a device which was originally designed to develop phrase reading. On the front there is a small window about seven inches long and one inch high. Reading material, usually of a story type, is printed in sentences on a rotating roll of paper and is shown through the window to the reader. Phrases, therefore, are exposed sequentially from left to right, by three small fluctuating slides in the window. As the last slide of one line of material is shown the roll rotates to the next line. By manipulating the speed of the roll and the fluctuating slides, the operator controls the length of phrase, and rate of reading.

Non-mechanical presentation was by means of graded paragraphs Mimeographed on paper  $8\frac{1}{2} \times 11$  inches. The material was selected from stories, the readability of which was determined by the Yoakam (29) Readability Formula. The paragraphs ranged in difficulty from first to twelfth grade.

All the material presented, both mechanically and non-mechanically, was new to the subject. Both easy and difficult materials were presented. Easy material was defined as having a readability level one and one-half grade below the subject ARL (actual reading level); difficult material was defined as having a readability level one and one-half grades above the subjects ARL.

### *Findings*

The findings in this study, as reported in this summary will be related to the seven specific objectives listed heretofore.

1. To determine the incidence of recorded implicit speech among a selected group of intermediate grade children.

It was determined that more implicit speech was manifested during a reading activity than during a non-reading activity. This was noted for both easy and difficult material. There was more recorded implicit speech during the silent reading of operationally defined easy material than during the reading of operationally defined difficult material. Also there was more recorded implicit speech manifested while reading at an operationally slow rate than during an operationally defined fast rate. The differences were significant at the .01 level of confidence.

2. To determine which of two groups of children, the reading achievers or the reading retardates, manifest a higher incidence of recorded implicit speech.

When comparisons were made between the two groups of children, the operationally defined achievers and retardates, the latter group manifested more recorded implicit speech under all experimental conditions. When the material was presented mechanically, both achievers and retardates manifested more recorded implicit speech during the reading of operationally defined easy material. Contrary to this, when the reading material was presented non-mechanically, both achievers and retardates manifested more recorded implicit speech when reading difficult material.

3. To determine the relationship between the incidence of recorded implicit speech and reading rate while reading silently.

The rate at which the reading material was presented varied from approximately 88 words/minute to approximately 200 words/minute. At each thirty-second interval the rate was increased. It was noted, that as the rate was periodically increased there was a decrement in recorded implicit speech. This observation was noted as both achievers and retardates read operationally defined easy and difficult material.

4. To determine at which rate of reading there is minimal incidence of recorded implicit speech.

As may be noted in the above, there was an inverse relationship between recorded implicit speech and the mechanical rate of presentation of silent reading material. A sharp decrement in recorded implicit speech was noted as the rate of presentation was increased from approximately 88 words/minute to approximately 107 words/

minute. From 107 words/minute to 182 words/minute approximately there was slight decrement in recorded implicit speech; however, from this latter rate to the limit of the machine, approximately 200 words/minute, there was little decrement in recorded implicit speech. It can be assumed, however, with a fair degree of confidence that among intermediate grade children, there will be little decrement in recorded implicit speech when they read silently in excess of approximately 180 words/minute.

5. To determine the relationship between the incidence of recorded implicit speech during silent reading and efficiency of comprehension.

It is interesting to note that the mechanical presentation of reading material influenced reading behavior. More implicit speech was manifested, and better comprehension scores were obtained by the retardates when easy reading material was mechanically presented. When difficult material was presented non-mechanically, again the retardates manifested a higher incidence of recorded implicit speech, but the achievers scored higher on comprehension.

6. To determine the relationship between methods of reading instruction (Basal vs. Basal with Supplementary Phonics-Phonetic Keys to Reading) and recorded implicit speech during silent reading.

To explore the relationship between recorded implicit speech and methods of beginning reading instruction, comparisons were made between two groups of children; one taught with the Basal Method and the second taught with a Basal Method supplemented with phonics. When both easy and difficult material were presented at both slow and fast rate mechanically, the children taught by the basal approach manifested more recorded implicit speech than did those taught by a basal approach augmented by a phonics program. When the material was presented non-mechanically, again the children manifested more recorded implicit speech, but the difference was not significant at the .05 level of confidence.

7. To determine the relationship between recorded implicit speech and selected language processes.

Are these relationships negative or positive? Does the mode of presentation influence reading behavior? While it is impossible to draw general conclusions concerning the relationship between re-

corded implicit speech and selected language processes, abstracting relevant data from the study reveals some interesting patterns.

The manner in which the reading material was presented determined whether or not the correlation between mental age, as determined by the Binet, and recorded implicit speech was positive or negative. This fact was true also as pertains to the correlation between words spelled correctly on the Spache Spelling Test and recorded implicit speech. The mode of presentation of the silent reading material had little effect upon the correlation that existed between recorded implicit speech and scores obtained on the following tests: STEP Listening Test, Wepman Auditory Discrimination Reading Test, Arithmetic Computation Part of the American School Achievement Test, McCullough Word Analysis Test, and errors made by the experimentees on the Gilmore Oral Reading Test.

In most instances, negative correlations were found to exist between recorded implicit speech and the language processes as measured by the tests listed above. Exceptions to the above statement were noted with scores on the Spache Spelling Test and Mental Age as determined by the Stanford Binet Intelligence Scale.

### *Conclusions*

One very significant conclusion that was drawn from patterns of scores is that implicit speech, as defined and measured in this study, is a natural adjunct of the reading process, that it is possibly a residue of initially learned oral language patterns, and furthermore that at appropriate times all of us use it as an additional sensory input into cortical functioning or that it is a secondary reinforcing agent.

At least five implications can be drawn from the data collected and observed behaviors of the experimentees, to wit:

1. No inhibitory measures should be taken to cause a decrement in its manifestation, and furthermore that a natural decrement will occur as students acquire maturity in reading skills,
2. That implicit speech may be a frame of reference when we wish to validate written language patterns as being consonant with our own natural rhythmic patterns of oral language,
3. That a psychologically and pedagogically sound method to cause a decrement in the manifestation of implicit speech is to organize the

optimal reading environment, and to judiciously manipulate it so that students will acquire maturity in reading and language skills,

4. That augmenting a basal program with emphasis upon phonics, does not, *per se*, result in an undue manifestation of recorded implicit speech,
5. There is some evidence that when reading material is mechanically presented to readers, more recorded implicit speech is manifested,
6. That implicit speech in silent reading may be a residue of earlier learned oral language patterns,
7. That it may be a reinforcing mechanism or an added sensory input into cortical functioning as the reader comprehends difficult material.

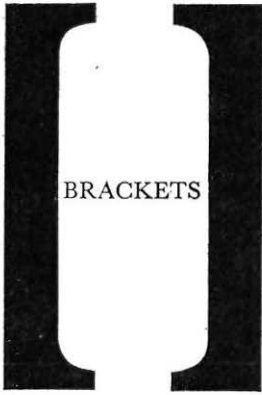
What other implications does this study have—let me think. *I say, says I to myself.* . . .

#### REFERENCES

1. Adrian, E. D., & Bronk, D. W. The discharge of impulses in motor nerve fibers. *Journal of psychology*, 1929, 67, 119–151.
2. Anderson, I. H., & Dearborn, W. F. *The psychology of teaching reading*. New York: Ronald Press, 1952.
3. Bain, A. *The senses and the intellect*. London: Longmans, Green, 1868.
4. Ballet, G. *Le langage interieur*. Paris: Aucionne Librarie Germer Bailliere et Cie, 1886.
5. Buswell, G. F. *Non-oral reading: A study of its use in the Chicago public schools*. Chicago: Supplementary Educational Monographs, 1945.
6. Clark, R. S. An experimental study of silent thinking *Archives psychology*, 1922, 48, 1–102.
7. Cole, L. *The improvement of reading*. New York: Farrar and Rinehart, 1938. P. 29.
8. Courten, H. C. Involuntary movements of the tongue. *Yale psychological studies*, 1902, 10, 93–95.
9. Curtis, H. S. Automatic movements of larynx. *American journal of psychology*. 1900, 11, 237–239.
10. Davies, W. C. Silent speech: Its development and current status in experimental research, clinical practice and classroom application. (Doctoral dissertation, University of Pittsburgh), 1963.
11. Edfelt, A. W. *Silent speech and silent reading*. Chicago: University of Chicago Press, 1960.
12. Egger, V. *La parole interieur*. Paris: Librarie Germer Bailliere et Cie, 1881.
13. Faaborg-Anderson, K. Electromyographic investigation of intrinsic Laryngeal muscles in Humans. *Acta. physiol. scand.*, 1957, 41, Suppl. 140.

14. Hansen, F. C. C., & Lehman, A. Weber unwillkürliches flüstern. *Philosophische studien*, 1895, 11, 471–530.
15. Harris, A. J. *How to increase reading ability*. New York : Longmans and Green, 1950. P. 72–4.
16. Hollingsworth, H. L. *Educational psychology*. New York : Appleton-Century-Crofts, 1933.
17. Jacobson, E. *Progressive relaxation*, Chicago : University of Chicago Press, 1956.
18. Max, L. W. An experimental study of motor theory of consciousness. *Journal of genetic psychology*, 1934, 11, 112–125.
19. McDade, J. E., A hypothesis for non-oral reading : Argument, experiment and results. *Journal of educational research*, 1937, 30, 489–503.
20. McGuigan, F. J., et al. Covert language responses during silent reading. *Journal of educational psychology*, 1964, 55, 339–343.
21. O'Brien, J. A. *Silent reading*. New York : MacMillan and Company, 1921.
22. Paulhan, F. Le langage interieur et la pensee. *Revue philosophique*, 21, 26–58.
23. Reed, H. B. The existence and function of inner speech in thought process. *Journal of experimental psychology*, 1916, 1, 365–392.
24. Stricker, S. S. *Studien über die sprachdarstellungen*. Vienna : 1880.
25. Thorson, A. H. The relation of tongue movements to internal speech. *Journal of experimental psychology*, 1925, 8, 1–32.
26. Tinker, M. A. *Teaching elementary reading*. New York : Appleton-Century-Crofts, 1952.
27. Toussaint, I. H. The interrelations of reading, listening, arithmetic, and intelligence and their implications. (Doctoral dissertation, University of Pittsburgh), 1961.
28. Wyczoikowska, A. The theoretical and experimental studies in the mechanism of speech. *Psychology review*, 1913, 20, 448–458.
29. Yoakam, G. A. *Reading and study*. New York : MacMillan and Company, 1928.

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Brackets are like a thin man and twin brother  
Head to head,  
Toe to toe,  
Standing facing each other.  
Though much like parentheses,  
Brackets are squarer.  
They're used when an editor  
Edits an error.  
For instance, "The mesengger [messenger] ran  
To get some [word missing]  
To hel[p] the poor man,"  
And also for putting in facts, such as "He  
[George Washington]  
Chopped down a [cherry] tree."

You'll learn, if you type.  
And it's bound to displease,  
That brackets aren't found among typewriter keys.  
You leave a small space  
For each bracket and then  
Go back and make brackets  
With pencil or pen.  
If you are a typist, thus treated unfairly,  
Be grateful that brackets are used very rarely.

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# The Durability of Fifteenth-century Type

Michael Pollak

From a review of references to early typecasting and typesetting practices, the author computes the amount of labor required to handcast 1,000 pieces of type in the fifteenth century, and reaches a figure of fourteen man-hours. As a means of determining the ability of the type to withstand succeeding blows of the platen and the other wear brought about by setting, cleaning, and distributing the type, he applies this labor cost to the publication of a fifteenth-century book, the works of Flavius Josephus printed at Venice in 1486, postulating different sizes of editions. Working on the assumption that excessive labor costs per copy would have made this book and others like it uneconomical to produce, he concludes that incunable type was able to withstand at least 10,000 to 20,000 blows of the platen but suggests that its life expectancy was actually much higher. He supplements his cost analysis by citing other evidence to show that incunable type was fairly durable.

No specimen of type metal, authoritatively identified as having been manufactured during the first few decades following the invention of printing, has yet been discovered. Maurice Audin, it is true, has concluded that certain type characters recovered from the bed of the Saône River at Lyons about 100 years ago are of either late fifteenth-century or early sixteenth-century origin [1, pp. 9–10]. The fact remains, however, that today there is absolutely nothing we can see, touch, or feel with the complete assurance that it is really one of the many millions of pieces of type cast for the 1,700 or more printing plants which flourished at one time or another during the incunable period. And even if we are fortunate enough to unearth a cache of unused fifteenth-century type some day, only a breakdown test of the unique find on a wooden handpress, using paper and ink similar to those of the incunable era, could provide us with a meaningful estimate of the durability of fifteenth-century type—which is to say, the number of impressions incunable type was capable of withstanding before it became too worn to continue producing work of acceptable quality.

The significance of the matter lies in the fact that the number of copies of a book which could be printed depended greatly upon the life expectancy of the type available to the printer. If type was so soft that it would wear out quickly, then a large edition was possible only if the printer could provide an immense quantity of type with which to do the job, or if he could replenish the type as it deteriorated. If, on the other hand, type was fairly durable, a printer who owned only a modest stock of characters could compose enough pages of text to fill a few forms, print those forms, clean the used type, distribute it back into the cases, and then repeat the process as many times as necessary, until he finished printing the edition. The ultimate selling price of a book, it must be stressed, was materially affected by the durability of the type used in its manufacture, for the cost of casting and finishing new type was very high [2, pp. 76–78]. Consequently, the direct and significant relationship between the life expectancy of type and the retail price of early printed books is a matter which merits investigation.

Quite obviously, the fledgling printing industry could not have survived very long as a self-sustaining economic entity unless it could meet and overcome the competition of the scribes, and then reduce the price of books sufficiently to create a broad and receptive market for them. Bühler has suggested that the products of the press may have been as expensive as manuscript work in the very early days of printing [3, p. 150 n]. If this is true, the high cost of type, prorated on a per-copy basis, must surely have played an important role in the establishment of the correspondingly high selling price for the printed book. Similarly, the decrease in the price of printed books in succeeding years should be attributed in great part to improvements in production techniques, including those pertaining to the durability of type.

We are handicapped in the investigation of early type, not only by our inability to study the type itself at first hand, but also by a scarcity of records from the incunable period which might throw light upon the subject. We know that lead, tin, and antimony were commonly employed in the manufacture of the metal,<sup>1</sup> and that other

1. It is not certain that antimony was used in the type alloy mix in the early part of the incunable period.

elements, such as silver and iron, were also used on occasion, although it is possible that the iron (or, at least the iron found in the types examined by Audin) existed only in traces, as an impurity [4, p. 92]. There appears to have been no uniform standard of procedure from plant to plant either in the metallurgical techniques employed or in the determination of the proportions of ingredients making up the type alloy. Accordingly, we cannot expect that all types manufactured in the incunabular era would bear up equally well in pressroom use.

No meaningful attempt can be made to provide a solution to the problem of the durability of early type until certain questions are taken into consideration. How do we define the point at which type becomes sufficiently worn so that we can say that it is no longer capable of yielding impressions of "acceptable" quality? Are we speaking of thin-faced types or bold-faced types, of small sizes or large sizes? Is the platen of the press made of wood alone, or is its underside sheathed in metal? Is the press equipped with some kind of mechanical stop to limit the downward travel of the platen, or will the platen come down crushingly onto the form if the pressman swings the lever somewhat too zealously? Is any packing material (blanketing) interposed between the platen and the paper lying on the type? What kind of paper and ink are being employed? Are the individual press runs so large that the type will undergo only a limited number of "wash-ups," distributions, and resettings, or are the runs so small that the type will be subjected repeatedly to the risk of damage and the increase in wear inherent in these off-press phases of the work? And, of course, how carefully is the type being handled by the workmen from the time it is removed from the cases until the time it is distributed back into the cases?

Even if we were able to provide specific answers to all of these questions, a precise determination of the durability of primitive type would still not be possible. If we were to ask a number of modern pressmen how many impressions may be anticipated from a font of new foundry type being used on a small platen press, the answers would vary widely. I asked several pressmen for such estimates, specifying a 10-point Futura Medium typeface on a small "snapper" press being operated under ordinary shop conditions, and received replies ranging from 25,000 to 100,000 impressions, although it was agreed that much larger runs could be expected if great care was

exercised throughout all phases of the work. Jackson says that type “will print, if not abused, hundreds of thousands of clear impressions before it wears out,” offering this as a rather broad estimate for modern power-driven letterpress work [5, p. 11]. Kubler reprints a document, dated March 11, 1806, entitled *Arbitration between the University of Cambridge and Andrew Wilson*, which states that “it is determined by the experience of the University of Oxford that a work entirely composed with moveable types, and kept standing, will print tolerably fairly 120,000 copies. Had this font of letter been subject to repeated distribution, repeated composition, repeated correction, repeated planing-over, and all the consequent damage that accompanies these destructive operations, it is fair to infer that not more than 100,000 impressions per form would have been obtained from it” [6, p. 39]. A year or two later, however, the printer and author, Thomas Hodgson, projected a much higher figure for type which is kept standing, “I have heard from good authority,” he wrote, “that from forms of a bible, or a testament, the types of which are kept constantly standing, at the University of Cambridge, no fewer than 500,000 copies have been printed” [6, pp. 65–66].

If we cannot arrive at a fairly exact figure concerning the life expectancy of type in our own times, or in comparatively recent times, how can we expect to do so for the type of half a millennium ago? Quite obviously, the best we can hope for is to ascertain whether early type was so soft that it would produce only a few hundred to a few thousand impressions, or whether it was hard enough to make as many as 10,000, 20,000 or 30,000 impressions possible—or even considerably more. It comes as no surprise, therefore, that some confusion exists today concerning the durability of fifteenth-century type.

“The type metal used in the fifteenth century,” reports the British Museum Catalogue, “appears to have been very soft, and the printer who desired to go on using the same fount was obliged to provide for its renewal. This could be effected either by a periodical recasting of the type in bulk, or by frequent additions to the fount supplementing a diminishing stock of any particular sort” [7, pt. I, p. xv].

Febvre and Martin express an opposing view as they open their discussion of type usage, asserting that incunable types (and also those of the next three centuries) were unquestionably durable,

although not, possibly, to the same degree as modern types [2, p. 74]. Yet they immediately follow this statement by informing us that Ambroise Firmin-Didot [8, pp. 99–101] had determined, in a study of the post-incunable Aldine Greek texts, that the type characters used in these edition wore out quickly, so much so that in 1570 Paul Manutius was still having problems with type, and was asking that fresh characters be cast for him every time he put a new book into production. If this were not done, Paul Manutius is reported to have written, the type would be worn out in four months, possibly in the middle of the printing of the book.

The reader is left with the impression that Febvre and Martin do agree basically with the contention made in the British Museum Catalogue that type was soft, in spite of their initial assertion to the contrary, for they reaffirm in the very next paragraph that “types wore out rapidly. The printers, therefore, had to replace them frequently; in this area they were faced with many problems for a long time” [2, p. 76].

In a previous paper dealing with production costs in early printing [9] I examined two copies of the works of Flavius Josephus, printed for Octavianus Scotus at Venice in 1486 by Joannes Rubeus Vercellensis [10, p. 360, item J-486],<sup>2</sup> and attempted to arrive at the costs (expressed in terms of hours of labor) for the printing of editions of 200, 300, 500, and 1,000 copies of the book. This earlier study did not analyze the cost of manufacturing the type needed by Joannes for the project. The present paper will investigate this aspect of the production of the book by Joannes, again expressed in terms of hours of labor. The purpose will be to establish, in broad terms, how durable early type was, primarily by computing how long-lasting it had to be before it would be financially feasible to print a book with the typographic characteristics of the Josephus volume—or, by extension, any other book.

The Josephus work is in folio. It consists of 274 printed leaves and 4 blank leaves (548 printed pages and 8 blank pages), each leaf measuring in excess of 310 mm × 212 mm. The type is set in one column of 56 lines per page, and the type area on the typical page is

2. One of the copies examined belongs to the Bridwell Library, Southern Methodist University; the other is the property of the author.

about 54 picas high by 34 picas wide. The bound book is made up of three separate works by Josephus: *De Antiquitate Judaica*, *De Bello Judaico*, and *Contra Appionem*. A single style of type, in one size only, designated as Proctor 82 R [7, pt. V, *Venice*, Facsimiles, pl. 36], is used throughout the book. This type corresponds fairly closely in size and weight, although not in appearance, to the 12-point Century type of our times. Each page of the book is estimated to contain, on the average, some 5,250 units of type, counting characters, spaces, and quads.

The bound volume is made up of 35 sections.<sup>3</sup> Two of these sections contain 12 pages each, while one contains 20. The remaining 32 sections have 16 pages apiece. In order to simplify our calculations and minimize confusion, it will be assumed henceforth that each of the book's 35 sections contains 16 pages of printed text. The liberties which are being taken will yield results only slightly at variance with those which would be obtained if we adhered rigidly to the conditions actually existing in the book. The minor discrepancies involved will be of no practical importance.

Since each page contains approximately 5,250 characters, a section of 16 pages would require 84,000 pieces of type. The entire book of 35 sections would thus call for 2,940,000 characters.

There is no way of knowing how much type Joannes had available in his shop when he printed the Josephus work, but we can be certain that he did not own enough to be able to compose the entire book in one fell swoop.

Since type was so expensive, it was imperative that the acquisition of new type be limited quite severely. Although printers generally did their own type casting, the high cost factors imposed rigid restrictions upon the quantity of type they could economically manufacture and store in the plants. Febvre and Martin state that when, later on, it became commonplace for printers to buy type, the practice developed of purchasing only minimal quantities, and that a font of type usually included between 60,000 and 100,000 pieces [2, p. 78]. Such a font, Febvre and Martin explain, would generally be adequate for the composition of no more than a few dozen pages at a time.<sup>4</sup> The printer

3. The collation is as follows: A-L<sup>8</sup>M<sup>6</sup>a<sup>10</sup>b-r<sup>8</sup>f<sup>8</sup>s-x<sup>8</sup>y<sup>6</sup>.

4. The typical page in the Joannes-Josephus contains many more characters than

was accordingly obliged to reset and reuse the same characters in the printing of a book, so that the font wore out rapidly. Febyre and Martin refer to a contract written during 1637 in which a typesetter sold a font, *très complète*, of more than 180,000 pieces [2, p. 170]. Even as late as 1637, apparently, a transaction involving so large a font was rather unusual.

Our calculations pertinent to the analysis of the durability of Joannes's type can be simplified considerably by making the following assumptions, unrealistic though they are:

1. Joannes owned about 84,000 characters, just enough to set the type for one section of 16 pages.
2. Each section required exactly the same number of *a*'s, *b*'s, *c*'s, etc. as every other section.
3. Joannes's font of 84,000 characters coincided sort for sort with the type requirements of every one of the 35 sections in the book.
4. The first section of the Josephus edition was composed and printed, the type therein was distributed, the second section was composed and printed, its type was then distributed, and so forth.
5. Not a single piece of type was destroyed or mislaid during the entire operation, there were no mistakes in the presswork, and no overruns or underruns of the press were required.

These assumptions are very far from being realistic. Nevertheless, they can be employed quite logically for our purposes. Joannes obviously must have owned considerably more than 84,000 characters in order to print anything of the magnitude of the Josephus work with any reasonable measure of economy and efficiency; but even if he had used several times 84,000 characters, it still would not have affected the durability of the individual pieces of type. What we are interested in determining, after all, is how many blows of the platen could be withstood by the type. Those pieces of type which were utilized to the extent of, let us say, 60 percent of their life expectancy would still have had 40 percent left for subsequent use by Joannes. The assumptions we are making at this point simply eliminate the need for the repeated application of correction factors to many of the figures which will be encountered as we proceed with our computations.

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most incunable pages. A font of as many as 100,000 characters would not have been adequate for more than about one and one-half dozen Josephus pages.

For a 16-page section printed in folio the imposition requirements are that Form No. 1 (pages 1 and 16) back up with Form No. 2 (pages 2 and 15); Form No. 3 (pages 3 and 14) with Form No. 4 (pages 4 and 13); Form No. 5 (pages 5 and 12) with Form No. 6 (pages 6 and 11); and Form No. 7 (pages 7 and 10) with Form No. 8 (pages 8 and 9).

Theoretically, Joannes could have produced a book of 35 sections, each of 16 pages, by composing pages 1 through 9 of each section as its turn came up for processing. He could have locked up pages 8 and 9 as Form No. 8, and printed this form. The type in these two pages could then have been distributed back into the cases. He would now have had enough type on hand to compose pages 10 and 11 for locking up with their conjugates, pages 7 and 6 respectively. The two forms thus created, Form No. 7 and Form No. 6, could then have been printed (on one or two presses) and the type distributed and set again as needed, until the book was finished. Such a procedure could have been carried out economically only in a plant operated at an awesome level of efficiency, and would have reduced the minimum number of characters required from our hypothetical (and unrealistic) figure of 84,000 to a mere 47,250 (an even more unrealistic quantity, representing enough type for nine pages, at 5,250 pieces per page). However, the life expectancy of each piece of type would still have remained the same.<sup>5</sup>

It is regrettable that today we have no fifteenth-century sources to consult for detailed information regarding early printing technology. Although a few scattered remarks on the subject are found in the colophons and within the texts of various incunable works, they are

5. In the earliest part of the incunable period, printing was done one page at a time, so that a printer who operated one press could get along with a very small stock of type characters, enough essentially to compose one page at a time. When the press run for one page was completed, the type could be distributed and then reset for the page immediately following it in the book. We may suppose, however, that a printer would prefer to own enough type to be able to compose at least one page while its predecessor was still on the press, in order to prevent his press from lying idle during the distribution and composition processes. The development of the technique of printing two or more pages on one form for subsequent inclusion in a section of the book created imposition problems which had not previously existed for the printer, and which made it necessary for him to own comparatively large quantities of type.

generally brief, and of limited value from the technical point of view. We do not encounter any mildly serious attempts to describe the mechanics of the craft until well into the sixteenth century, but even these are abbreviated and inadequate. The first edition of Vannoccio Biringuccio's *Pirotechnia*, a treatise dealing with the entire field of metallurgy as then known, appeared in 1540; it allocated only a few sentences to printing and typefounding [11, pp. 374–76]. Although this material was slightly enlarged beginning with the second edition, issued in 1550 [11, p. 374 n], the *Pirotechnia* contains, all told, no more than a few hundred words on the art of printing; and, except for giving us a breakdown of the ingredients of the type alloy mix, yields little of value in the study of the durability of early type. Nor is there much to be learned in this connection from the other sixteenth-century works which deal peripherally, or rather sketchily, with printing, such as Leonardo Fioravanti's *Dello Specchio di Scientia Universale*, published in Venice in 1567, and the *Eygentliche Beschreibung aller Stände*, with text by Hans Sachs and woodcuts by Jost Amman, a curious compendium of contemporary vocations, issued in Frankfurt in 1568. A pamphlet devoted completely to the related subjects of calligraphy and printing, attributed to Christopher Plantin and published by him in 1567, also provides only skimpy details [12]. There are a number of woodcuts, the earliest of which appeared in 1499, depicting print-shop employees at work, but these are of little worth for our purposes in this study, and some are of dubious accuracy. Here and there, from correspondence and contracts, it is possible to glean a few pertinent and enlightening facts. However, we are compelled to depend upon the work of that energetic Londoner, Joseph Moxon, for most of the technical information available concerning early printing methods—although Moxon's book did not appear until 1683–84, two centuries after Joannes had printed the Josephus volume [13]. It is therefore imperative that we proceed gingerly as we examine Moxon's description of printing practices, and try to apply the seventeenth-century techniques he describes to a shop of the period of Joannes.

Actually, there had not been many significant improvements in printing equipment from the incunable decades until Moxon's day. Most of the progress could be classified as belonging in the "tricks of the trade" category. If, by some miracle, Joannes Rubeus Vercellensis could have been transported over the intervening 200 years to

re inquit in montibus abscondas: arbutatus fortitudinem te habere: sed si confidas tuæ uirtuti  
descende: quatenus per caput nostri milites configant: & fortissimi belli euentus demonstrerit ui-  
diorum meis uel tuis. Scito tamē optimos ab unaquaque ciuitate mihi cōmittentes iustosq; sen-  
tus tuos proauos euicerunt. Contra nos alias nobis aut in tali terra certandū est: ubi non lapidi-  
bus sed armis decet fortissime præliari: ne sit locus tibi quo ualeas deuidus esfigere. His inci-  
perat ionathas: decem milia militum eligens: ab hierosolymis egreditur cum fratre symone: per-  
uenitque ad ioppem: castra iuxta ciuitatem disposuit. Nam ioppenses portas concluderant: in-  
tra habentes custodias ab appollonio constitutas. Cūq; ionathas obsidere parasset eos: timētes  
ne suam ciuitatem deualaret portas aperit. Appollonius uero captam audiens ioppem a iona-  
tham: tria milia equitum sumens: & octo milia pedum ad azotum peruenit: & exinde tacite pau-  
latimq; uiam sibi perfecit. Cum ergo uenisset i ioppem tanquā recedēs: ionatham trahit ad cam-  
pam: confidens equitibus & spē in eis habens suæ uictoriæ. Cūq; processisset ionathas: sequen-  
tur usq; ad azotum appollonius: qui cum ad campum uidisset hostem uenisse: conuersus pugna-  
cum eo cōmisit. Mille itaq; equites appollonius ad insidias in aliquo torrente disposuerat: qui re-  
tro inimicis insisterent. Quod sentiens ionathas: non est turbatus: sed ordinans in quadro exer-  
citurus: per ambas partes inimicos exciperent: hortatus est: ut fortiter ante uel retro pugnantibus  
ubiq; resisteret. Prælio aut usq; ad uesperam procedente: dāns fratri symoni partem exercitus  
exercitus: iussit aduersarioq; eum aciem inuadere: suisq; preceptis: restudine facta sagittas equitū exci-  
pere. Qui cum præcepta fecissent nihil letebātur: quāuis hostes super eos frequentia tela libraret:  
usque quo suas euacuasent pharetras. Nam sagitte corpora clipeis septa: minime cōtingebant:  
cum conspatione restudinis tela uenientia refugarentur. Cum uero a primo mane usq; uespe-  
re iaculantes aduersarii descensissent: intelligens symon lassos eos: inuadit aciem: fortiterq; eū suis  
militibus dimicans: fugauit inimicos. Vidēs aut equites pedites ad fugā conuersos: & spē corū  
decepti sine decore & turpiter abscesserunt: & per oēm campum dispersi fugierunt. Quos secu-  
tus ionathas usq; ad azotum multos occidit eorum. Qui de sua salute deperantes: ad templum  
dagonis cōfugerunt: qd erat in azoto. Captiens aut incurisione sua ciuitatē ionathas: incēdit eā: &  
omnes circa eam uicos: neq; peperit templo dagonis: sed etiam flammis consumpsit: & eos q;  
sibi confugerant interfici. Multitudo uero quæ in illo concidit prælio una cum illis qui in templo  
confugerant: octo milia fugerunt. Vincens ergo tantū ionathas exercitum: ab azoto discessit: &  
ad ascalon uenit: & foras ciuitatem castra constituens: terni ascaloniter: in occursum ei exierunt  
dona portantes. Qui laudans eorum uoluntatem reuersus est ad hierosolymam: multa prædā fe-  
rens: qui uidebatur a uictis hostibus abstulisse. Alexander autē deuidus audiens ducem suum  
appollonium: simulauit gaudium: q; præter eius sententiā cum ionathā confuisset: qui eius ami-  
cus erat: mitititq; testimonium ionathæ: præbēs præmium & honorem: & torquē aureum: sicut  
solet affinis regis dari: eiq; commisit accaronis prouinciæ magistratum.

Capitulum. VII.

Odem tempore: rex ptolomeus philometor dictus: naualem ducens exercitum & pe-  
dites: ad syriam ueniebat: alexandro suo genero solatia præbiturus. Quæ omnis ciui-  
tates studiose alexandro præcipiente suscipiebant: & deducebant usq; ad gazorum:  
ubi oēs clamabant: acculantes ionathan q; templū incendisset & destruxisset: pun-  
ciamq; uastasset: multosq; eorum interemisset. Quæ ptolomeus audiēs tacuit: ionathas autē i iop-  
pen occurrit ptolomeo dona clarissima uel honorem ab eo percipiens: & producus eum usq;  
ad flauium qui cleutherus appellatur: ad hierosolymam remcauit. Perueniens ergo ptolo-  
maidem: præter omnē spem paulominus habuit interfici ptolomeus insidiis alexandri: quas ei  
per ammoniū amicum parauerat. Manifestis aut factis insidiis ptolomeus alexandro scribit: quas ei  
nam ammoniū petens: & dicens insidias se ab eo passum: & uindictā sumere iussit esse. Alexandro  
uero non concedente ptolomeus intellexit illum causam insidiarū extinxisse. Quapropter ei sa-  
ctus est odiosus. Antiochenis autē prius erat odibilis alexander propter ammoniū: multa nūq;  
per eum passi fuerat: & poenā quidē ab ammonio pro eius delictis exegerunt: occidentes eū qui  
tanquā mulier se pperabat abscondere habitu circumdatus femineo: sicut alibi dictū est. Pto-  
lomeus itaq; acculans eum ut patrem nuptiæ filiz suæ: transgressorēq; auxilii quod ei  
contra demetrium deduxisset: soluit affinitatē. Nam & auferens suam filiam: ad demetrium legatio-  
nem direxit: amicum cum eo cōponens: sicut datose se illi uxorem: & restituere paterno cum  
principatu cōpromittens. Demetrius uero gaudēs: suscepit legationem & nuptias. Tum nimis  
iam ptolomeo labor restabat: fleclere antiochenos: ut demetriū susciperent: nam inimici eius  
fugerunt: eo q; a parte eius demetrio multa pessima passi fuissent: & alexandro tamen antiocheni

propter ammoniū irascebatur: ut prædiximus. Qui pulsus ab antiochia: in ciliciam usq; puenit. Ptolomeus ergo ad atiochenos ueniens: rex ab illis & militibus ordinatur: coactusq; duo sibi diademata superposuit: unū asyæ: alterum egypti. Benignus autē & iustus existens: nec concupiscens aliena: sed & futura prouidens: regulare regnū decreuit: ne romanos offenderet: ideoq; antiochenos in contōne congregans: flecit eos ut demetriū susciperent: dicens eum nequū pro patre dolorem seruaturū: si bene mereretur ab eis: doctore autē i bonis & ducē se illi esse: nec se fallacibus negociis immiscere: sibi autē dicebat egypti regnū sufficere. Quæ differens flecit antiochenos: terramq; atiochenosq; pdāte ptolemeus cū genero cōtra eū duxit exercitum. nā iam filiā suā matrimoniali iure demetrio contradiderat: & uincens alexandriā: ad arabia fugauit eū. Cōgrit autem in phouat equus ptolemei uocē elephātis audiens: ptolemeū iactaret. Quod eū uidit illi hostes: impetum sup eū fecerūt: multisq; uulneribus caput eius pforātes: ad piculū mortis eum adduxerunt. Sed custodes corporis eius rapientes eū liberauerunt: & ita p quatuor dies defechus iacuit: ut nec loqui nec intelligere potuisset. Alexandri uero caput arabū potentissimus zabilus abicidens ptolemeo transmisit. Qui die quinto releuatus: a uulnere dolore: suauē sibi rem summuq; spectacula alexandri morte simul & capite uidit: qui tamen paulopost uitā finiuit: pro alexandri morte gaudio summo cōpletus. Regnauit ergo asyæ alexander qui dictus est balans: annis quinq;: sicut i aliis demonstratū est. Suscipiens uero picipatū demetrius qui nicanor appellabatur: fraudibus corrupē cepit ptolemei militiā oblitus: & q; focer eius & auxiliator fuisset: & affinis per connubiū cleopatæ. Quapropter milites ptolemei ad alexandriā cōfugerunt: elephātes autē demetrius comprehendit. Ionatas interea princeps sacerdotū ex omni iudea sibi milites cōgregās: arcem hierosolymog; obfidebat: ubi custodia macedonū: & transgressoz; multitudo locata uidebatur. Et hi quidē contēbant ionathan facientē machinamenta: confidentes loci munitionibus. Noctū uero quidē multiuoli iudei exeuntes: uenerunt ad demetriū: arcis obfidiōē nūciantes. Qui nūcio incitatus: exercitū contra ionathan ab antiochia eduxit. Cūq; ad ptolemaidem peruenisset: scripsit ionathæ: picipiens ad ptolemaidē eū citius occurrere. Ionathas autē obfidiōē quidem minime soluere decreuit: seniores uero populi & sacerdotes congregans: & aux; & argētū & uesticū multitudine donoz; deportans: ad demetriū usq; puenit. Quæ cū obtulisset: irā eius moluit: & honoratus firmū ab eo principatū sacerdotū suscepit: quē a regibus ante ipsum donatum possidebat: accusantibusq; eū transfugas: demetrius eis non credidit: sed & petēti quatenus pro omni iudea: uel tribus prouinciis: samaria: uel ioppe: uel galilea: trecenta tantum daret talenta: fratris gentiq; iudeoz; salutē. Exemplum epistolæ quā lasteni cognato nostro scripsimus: transfugissimus uobis: ut eam noueritis. Rex demetrius lasteni patri salutē. Iudeoz; genti uobis amice: nostraq; iusta seruanti: pro fide decreui dona pberē: & tres possessiones afferem: bescleda: uel ramathe: quæ additæ sunt iudeis de samaria: & his arrentia: & quantacūq; ab immolantibus hierosolymog; reges accipiebāt ante me: uel quæcūq; de fructu terræ: uel patatis: & omniaq; alia quæ nostro competunt iuri: uel paludes salis: uel pro coronis quæ uobis offerebantur eis cōcedo: & nihil extorqueatur ab his ammodo & ipostez;. Cura igitur ut huius epistolæ fiat exēplar: & detur ionathæ: quatenus in nobili loco tēpli reponatur. Hæc scripta fuerant. Videns ergo demetrius pacē nullūq; supesse periculū: nec belli timorē: soluit exercitū stipendiisq; eoz; iminuit: & solis illis sumptus pbebat: qui cū eo a creta uel aliis insulis uenerāt. Vnde odiū uel inimicitia militum cōtra eū cōhatæ sunt: quibus ipse quidē nihil pbebat: reges uero ante ipsum eis ānonas etiā in pace submittrabant: ut eos in certaminibus si oporteret pro se fideles & pronos hēnt: atq; paratissimos in re bellica & pacis cū omni haberent confidentia expetere.

#### Capitulum. VIII.

Nrelligēs itaq; odiū militū circa demetriū alexandri qdā dux apamēnus genere: diodotus nomine: qui & trison dicebatur: uenit ad malchū arabū: qui filiū alexandri antiochū nūtrierat: manifestansq; ei inimicitias exercitus quas contra demetriū habebāt dari sibi petebat antiochū: nā regē eū facere: uel paternū principatū ei se restituere dicebat. Qui primū resistebat: minie credens: post uero multo tpe trifone petete: uincit malchus: flexusq; uolūtate sua est ad ea q; trison petebat. Princeps autē sacerdotū ionathas capere uolens arcē hierosolymog;: & iudeos transfugas: uel ipsos oēsq; qui p totā puincia custodes erant: transmitrēs ad demetriū legaros cū donis: rogabat ut de castellis iudeæ custodes eieceret. Cui rex nō hæc tātū se pberē: sed etiā his maiora pmittebat: post finē belli qd præ mātibus habebat: petebat uero eū & auxilia trāsmittre: mādās q; exercitus suus ab eo recelisset. Tūc ionathas tria milia militū eligēs destinauit.

the shop of Joseph Moxon, he would surely have been greatly impressed by the procedural advances which had been made in that long span of time, but he would have seen very little in the way of tools and machinery that was completely strange to him. Nevertheless, the improvements in foundry techniques, press operation, and the other activities carried on routinely in printing shops had been substantial. We must assume, therefore, that a printer in Joannes's time could not perform his functions as rapidly or as efficiently as a printer in Moxon's day. It is essential that we bear this in mind as we read Moxon.

The cutting of a full set of punches was in itself a very costly affair. From such a set it was then necessary to strike rough matrices (one for each punch in the set) and to justify, or finish, them, procedures which added greatly to the already high costs. On January 16, 1576, ninety years after the publication of the Joannes-Josephus, according to Voet [14, pp. 44–45], the punchcutter Hendrik van den Keere wrote a letter to his customer, the eminent printer Christopher Plantin, concerning the “jolye romain” type font which he was preparing for Plantin [15, vol. 5, p. 698]. In this letter, van den Keere explained that it took him more than a full day to cut each character in a font, and that the making of five or six matrices required an additional day. He estimated that he could complete the cutting of the punches in about three months, and that the processes of striking and justifying the matrices and making the molds would take four more weeks. Having thus prepared the ground, van den Keere then explained why it was going to take even more than four months to complete the work. If Plantin wanted to be sure that proper care could be given to all the details of the job, van den Keere cautioned, he would be well advised to allow two more months for that purpose. In other words, van den Keere was figuring on about six months of his time (plus the time of the people who may have been helping him) to prepare a set of punches and the necessary appurtenances.

A cursory survey of van den Keere's computations will reveal that the font he was cutting for Plantin could not have exceeded five or six dozen characters in number and was, consequently, a comparatively small font, for it could not have included much more than an alphabet in upper- and lower-cases, the numerals, and a few points and ligatures. An incunable font generally required many abbreviations,

ligatures, contractions, and points, so that an average-sized font in Joannes's time contained more than 100 units, and would therefore have taken much more time to cut than the font which van den Keere made for Plantin.

It is perhaps not out of order to suspect that van den Keere did not want to be rushed by his customer, and was tacking on two months to his normal schedule for reasons which had less to do with quality control than with keeping Plantin from pressing him unduly for early delivery. Of course, whether it took four months or six months, the job was very expensive, all the more so since it called for craftsmanship of the highest order.

One set of punches could have been the source for the creation of an indeterminate number of matrices. Vervliet states that "several dozens of strikes can be made with one set of punches" [16, p. 7], but an incunable printer who was more interested in keeping costs down than in producing work of quality could readily have gone well beyond the limits set by Vervliet. Each set of matrices could, in turn, have been used for the casting of a large number of characters. How much of the time devoted to the making of a set of punches and its auxiliary items should be apportioned as a labor cost to each thousand impressions of the type derived from these punches, should now be considered.

Let us begin by returning to van den Keere's estimate of six months for the cutting of a set of punches and the preparation of the accompanying matrices and molds, but let us also assume that in these six months he made a full-sized font rather than the smaller one he actually prepared. This will serve to compensate, to some degree, for the possibility that he was exaggerating his time requirements in the letter to Plantin. Let us also assume that van den Keere, like his contemporaries in the printing trade, observed the many holidays then in vogue. He would thus have worked, according to Oswald [17, p. 365], about 120 days in the six-month period.

When the typesetters eventually received the matrices from van den Keere, they naturally cast more of the frequently used characters than those which appear less often, so that the degree of wear incurred by the individual matrices within a set differed in proportion to their use by the typesetters. Unless replacements for the worn-out matrices were then struck from the punches, the first matrix to be

come no longer usable would put an end to the value of the entire set. The remedy was to strike new matrices as the need arose. Consequently, the individual punches in a font also wore out at varying rates.<sup>6</sup>

To attempt to compute the number of type characters which could have been derived from a set of punches would constitute an exercise in futility; to attempt to determine the number of man-hours required to cut punches and strike matrices for, let us say, each 100,000 pieces of type made would be an equally unrewarding experience, unless we knew the total number of characters which were actually produced from these punches. If we accept the van den Keere figures, it can be stated that in the case where only 100,000 units of type were made from a set of punches, the labor cost of that set of punches and its accessories was 120 man-days, or 1.20 man-days per 1,000 characters—conversely, 1,000 characters in 1.20 man-days, or 833 characters in one man-day. If 200,000 characters were produced from the one set of punches, one day of the punchcutter's time would have to be applied as a labor cost figure to the casting of each 1,667 characters, and so forth. No labor cost allowance is being made here for the restriking of matrices.

We may assume that the efficient printer tried to squeeze out as much use as possible from his punches, so that the number of characters eventually obtained from each set of punches would probably have run into many hundreds of thousands, if not into millions. It appears safe to assert that while punch (or matrix) deterioration did, of course, represent a necessary expense to the printer, it was not *critically* significant in the calculation of the cost of type and, consequently, in the cost of each thousand impressions produced with the type. This would have been true, of course, only if the type was utilized quite extensively. However, in the case of a type which received very little actual use, such as a type employed exclusively for headings, the cost of cutting the punches from which this type was ultimately derived must have been fantastically high in relation to the number of pieces

6. The rate of deterioration of punches and matrices would also be affected, of course, by other considerations, such as the size and design of the letter, the kind of metal of which the matrices were made, the care exercised by the workmen, and so forth.

cast and the number of impressions to which these pieces were subjected. Nevertheless, even when a type received substantial use, the factor of punch and matrix wear could not be ignored completely, for if, let us say, a million pieces of type were cast from one set of punches, the punchcutter's time outlay would have amounted to nearly one-eighth of a man-day for each 1,000 of these characters.

The labor costs for the cutting of the punches for Proctor 82 R, the type in which the Josephus work was composed, must have been rather low in relation to the number of pieces of type eventually derived from these punches, for Type 82 R underwent very extensive use over a period of many years. Information extracted from the British Museum Catalogue [7, V, pp. xxxviii, 414–22; VI, pp. 896–97], Goff [10, p. 711, and items referred to therein], and the British Museum *Short-Title Catalogue* [18, pp. 931–32, 978] indicates that Joannes Rubeus Vercellensis was engaged in the printing business, first at Treviso and then at Venice, from 1480 to 1519, that his brother Albertinus Vercellensis was his partner for some time, and that he also printed a number of books in association with Bernardinus Vercellensis. During this period of four decades, the Vercellensis brothers had a hand in the printing of at least 100 books. The British Museum Catalogue, which limits itself to works published during the fifteenth century and which provides typographic data concerning these works, lists forty books printed by Joannes and Albertinus. Of these forty, thirty were composed, either entirely or substantially, in Type 82 R; at least one other printer, Matteo Capcasa [7, V, p. 482], used the Vercellensis 82 R for the production of several books.

Those editions listed in the British Museum Catalogue in which 82 R is the only, or predominant, type contain some 10,000 pages of crowded text including, I estimate, nearly as many characters on the average page as there are in the Josephus work. I have not attempted to determine whether 82 R was used in the composition of those Vercellensis (or Vercellensis-related) books which do not appear in the British Museum Catalogue; and I have also disregarded the fact that 82 R almost surely occurred frequently in other products of the Vercellensis shops, such as ephemera and books of which no record exists today. Nevertheless, even if we restrict our computations to the 10,000 pages of 82 R noted by the British Museum Catalogue, we conclude that the Vercellensis compositors must have set, during the last

two decades of the fifteenth century, some 50,000,000 pieces of that type alone. This achievement, equivalent to composing seventeen volumes, each of the size and typographic specifications of the Josephus work, makes it obvious that the Vercellensis inventory of Type 82 R was replenished frequently. The typefounders must have been kept very busy casting enough sorts to see to it that the compositors' cases were properly stocked.

The fact that 50,000,000 characters of 82 R were composed does not mean, of course, that 50,000,000 characters were cast. Type was made, used for setting a number of pages of text, put on the press for whatever run was specified, washed, distributed, and then set again. New type was manufactured as needed; the total amount of type eventually cast to meet the requirements of the compositors was a function, in the mathematical sense, of the life expectancy of that type.

It would appear that Joannes obtained a set of punches in 82 R during or before 1480, struck matrices from these punches, and made his original font. Time and again, as the years passed, his typefounders cast replacement and additional type from the matrices, striking new matrices as the old ones wore out. When a punch was no longer up to the standard of quality demanded by Joannes, a substitute was cut. The possibility also exists, in light of the evidence accumulated by Harry Carter regarding the type acquisition practices of the early printers, that all, or part, of the type manufacturing processes—from the cutting of the punches to the casting and finishing of the characters—could have been contracted out to others [19, chap. 5]. In either case, the labor costs for the cutting of the punches and the making of the matrices, we may surmise, could not have been very significant when a type was used as thoroughly as the Vercellensis 82 R.

No attempt will be made in this study to estimate the amount of labor which went into the preparation of the type alloy needed by the typefounder for casting the type, although this operation, according to Moxon, was “labour would make *Hercules* sweat” [13, p. 167]. So grueling was the work, we are told, that its completion was gratefully marked by a time-honoured ritual which unquestionably took priority over all the other activities in the plant, and which was supposed to help the workmen gird themselves for the exertions which

still lay ahead. Moxon describes this essential step in the manufacture of type in sympathetic detail, telling us that “Now (according to Custom) is Half a Pint of Sack mingled with Sallad Oyl, provided for each Workman to Drink; intended for an Antidote against the Poysonous Fumes of the *Antimony*, and to restore the Spirits that so Violent a Fire and Hard Labour may have exhausted” [13, p. 167].

The flagging energies of the foundrymen having been revived, the casting of the type followed. The alloy was melted, and the type-founder then poured the molten metal into the mold, a technique requiring a great deal of skill. A separate casting was needed to make each and every letter. Legros and Grant describe the procedure in this manner: “In the early days of typefounding the metal was first melted into a pot from which it was taken in a ladle and poured by hand into the mould. This was jerked upwards by the founder with a peculiar and dexterous motion, so as to cause the liquid metal to reach the matrix at its end and so obtain a cast of the impression previously made by the punch” [20, pp. 16–17].

The speed at which this work could be accomplished is specified by Moxon. “A Work-man,” he says, “will *Cast* about four thousand of these Letters ordinarily in one day” [13, p. 173.]. However, P. S. Fournier *le jeune*, writing in 1764, about eighty years later than Moxon, puts the number at 2,000 to 3,000 a day [13, p. 173 n]. The discrepancy between the two estimates is substantial, and the fact that the figures presented at the later date show a lower daily production capacity is rather surprising. One would expect that with the passage of time and the growth of technical expertise, Fournier’s contemporaries would have been able to make at least as much type in a day as the foundrymen of Moxon’s time. It may be, however, that the craftsmen of Fournier’s acquaintance worked fewer hours each day than the men Moxon knew, or that they simply did not work as hard, or as well. It may also be that neither Moxon nor Fournier kept precise figures on foundry production, but that each was merely quoting rather general estimates of the number of type characters which, in his opinion, could be expected from each man-day of labor. It appears reasonable to assume that the daily production rate lay someplace between the lower limit of 2,000 characters proposed by Fournier and the higher quota of 4,000 advanced by Moxon. This assumption is lent credence by a statement made in

1750, in the *Universal Magazine* [21, p. 278], that a man could cast 3,000 letters in a day. Since this figure coincides with the average of the two extremes provided by Moxon and Fournier, it is being accepted as the basis for further computations in our analysis of type manufacture costs. However, a caveat should be noted here—the typefounder in the very early years of printing must surely have produced fewer pieces for each hour he worked than his successors in the craft two or three centuries later. This lower hourly rate, on the other hand, could have been offset by the fact that the incunable craftsmen may have worked more hours per day than did the later generations plying the same trade.

The rough casting which emerged from the typefounder's mold had to be converted into the finished character which the typesetter could place into his composing stick. This metamorphosis was effected by routing the casting through a series of operations which, in total, consumed much more working time than the process of casting itself.

The steps by means of which the rough castings were transformed into usable type characters are painstakingly detailed for us by Moxon [13, pp. 173–90]; it becomes obvious from reading his description that the necessary finishing work on the castings was tedious and time-consuming.

The length of the working day during the fifteenth century varied from place to place, but it appears that it consisted, in the average print shop at least, of about fourteen hours.<sup>7</sup> The casting of 3,000 characters per day would thus represent a rate of one piece every sixteen or seventeen seconds. Moxon's description of the steps following the casting process indicates that it must have taken considerably more time to finish each character than it did to cast it. The reader who wishes to pursue this matter more thoroughly is referred to the Moxon account; and it is suggested that he try to estimate how

7. Febvre and Martin have listed four examples of daily working hours in print shops during the first two centuries following Gutenberg. The average working day appears to have been about fourteen hours long [2, p. 198], although by the time of Moxon and Fournier the working day may not have been as long as it was when Joannes was operating his shop. In fact, one of the major objectives of the workers in the numerous strikes which took place in the printing industry during the post-incunable period was the reduction of the length of the working day.

much time it would have taken, per character, to carry out each of the operations which Moxon describes. The total of the time consumed by all these operations will be substantially greater than the sixteen or seventeen seconds which have been computed for the casting of each piece of type. It should also be remembered that this estimate of sixteen to seventeen seconds has been calculated backward, so to speak. We accepted 3,000 pieces as the total output for a day of fourteen hours, during which there must surely have been quite a few interruptions in the work, such as pauses for refreshment and chatting with fellow-workers, stoppages while waiting for materials, and all the other time-consuming breaks which inevitably crop up in a long working day. To the time estimates made by us for each step in the finishing processes listed by Moxon, we should, accordingly, add a bit more in order to make up for such stoppages during the day.

I believe that it must have taken at least twice as much time to finish the type and put it into the cases (or package each sort separately for shipment elsewhere) than it did to perform the casting work itself.<sup>8</sup> If this is correct, then the time required to process each 1,000 pieces of type from beginning to end would have been at least fourteen hours of labor, a figure which represents a rate of seventy-one pieces per hour, or somewhat more than one unit of type per minute. I am inclined to the opinion, I should add, that the work actually proceeded much more slowly than this, so that the cost of type characters, expressed in terms of man-hours of labor, was greater than the fourteen hours which have been allocated per 1,000 pieces. Nevertheless, this figure, inadequate as it appears to be, will be used here.

If we assume, accordingly, that Joannes owned 84,000 pieces of type, and that it took one man-day of fourteen hours to cast and finish each 1,000 units of this type, then the manufacture of Joannes's inventory of 84,000 characters required eighty-four man-days, or 1,176 man-hours of direct labor.

It should be emphasized that the direct labor which has been

8. I discussed this matter with Roger Levenson, lecturer in librarianship, University of California, Berkeley, and proprietor of Tamalpais Press. Mr. Levenson, who has personally done a good deal of handcasting and finishing of type, agrees that the finishing processes consume at least twice as much time as the casting work.

considered here has not included any allowances for the time devoted to the making of the punches, matrices, and molds, or to the melting and mixing of the ingredients which made up the alloy. We have also failed to allot any time for such indirect labor items as the hauling, delivery, and storage of the fuel and raw materials used in the manufacturing of the alloy, running errands, cleaning furnaces, starting and feeding fires, maintenance work, supervisory labor, labor resulting from inefficiency, waste, and human error, and so forth. I am, therefore, adding one-third more labor time to the direct labor figure of 1,176 man-hours which has been computed, so that the adjusted labor charge for making 84,000 pieces of type now becomes 1,568 man-hours. Although this adjustment of  $33\frac{1}{3}$  percent is completely arbitrary, I believe that it is, in fact, much too low. (It will be recalled that the punchcutter's time expenditure for the cutting of punches, in the case where a million characters were ultimately derived from these punches, was by itself computed at nearly one-eighth of a man-day for each 1,000 characters—which is to say, that this item alone could have accounted for about 12 of the  $33\frac{1}{3}$  percent being proposed here as the appropriate increment.)

To facilitate our computations, we have postulated that Joannes used the same 84,000 pieces of type thirty-five times in printing thirty-five sections of the Josephus volume. Consequently, each piece underwent exactly thirty-five impressions in the printing of each copy of the book. Since it required 1,568 man-hours of labor for the manufacture of 84,000 units of type, it follows that if this type was so soft that it would withstand only (let us say, for the sake of illustration) thirty-five blows of the platen, then all of these 1,568 man-hours would have had to be charged to the printing of one copy of the Josephus. It is also evident that it would have been possible to print about twenty-nine copies of the book for each 1,000 impressions which the type was capable of withstanding ( $1,000 \text{ impressions} / 35 \text{ impressions per copy} = 28.6 \text{ copies}$ ).

We are now able to write a simple mathematical equation to demonstrate the relationship—under the conditions postulated in this study—between (1) the life expectancies, at various levels, which Joannes's type could have been capable of sustaining in the printing of the Josephus work (the number of impressions which the type could withstand at any level being designated as  $N$ ); (2) the number of

books which Joannes could have produced with his 84,000 pieces of type at each of these levels ( $N/35$ ); and (3) the prorated labor costs per copy (expressed in man-hours, and designated as  $L$ ) at such levels:

$$L = \frac{1,568}{N/35}$$

Table I has been constructed by substituting quantities ranging from 1,000 to 50,000 for  $N$ . All figures have been rounded out to the nearest full number.

Column  $N/35$  in Table I includes listings for edition sizes of 200, 300, 500, and 1,000 copies, since these were the edition size figures which were analyzed in the earlier paper on the labor costs involved in the production of the Josephus work. The corresponding  $N$  and  $L$  quantities have been entered in their appropriate positions in Table I.

Table II has been abstracted from the earlier study, and lists the number of man-hours of labor—including an augmentation of one-

TABLE I. *Labor Requirements for the Manufacture of Type in the Production of the Joannes-Josephus at Various Levels of Type Life Expectancy*

<i>Number of Impressions Type Is Assumed To Be Capable of Withstanding</i>	<i>Number of Copies of the Book Which Could Be Produced at Each Level of Type Life Expectancy</i>	<i>Number of Man-Hours Needed to Manufacture Type for Each Copy Produced</i>
( $N$ )	( $N/35$ )	( $L = \frac{1,568}{N/35}$ )
1,000	29	55
2,000	57	27
3,000	86	18
4,000	114	14
5,000	143	11
7,000	200	8
10,000	286	5
10,500	300	5
17,500	500	3
20,000	571	3
30,000	857	2
35,000	1,000	2
40,000	1,143	1
50,000	1,429	1

TABLE II. *Labor Requirements for Composition, Presswork, and Bindery Work in the Production of the Joannes-Josephus in Various Edition Sizes*

<i>Processes</i>	<i>Number of Man-Hours by Size of Edition</i>			
	200	300	500	1,000
Number of man-hours required for composition, presswork, and bindery work	9,969	12,488	17,525	30,119
Number of man-hours per copy produced (to nearest man-hour)	50	42	35	30

third to allow for indirect labor, at least in part—which Joannes would have had to expend for composition, presswork and bindery work (exclusive of the actual covering of the book) for editions of 200, 300, 500, and 1,000 copies.

If we now draw up Table III by adding the appropriate figure from column *L* of Table I to each of the figures on the bottom line of Table II, we will obtain the per-copy number of man-hours of labor needed in edition sizes of 200, 300, 500, and 1,000 copies to perform all the work described in the earlier study and, in addition, to cover the manufacturing of the type. The number of impressions which the type would have had to be able to withstand in order to produce each edition size (column *N*, Table I) is also indicated in Table III, as is the percentage of the overall labor time attributed to the manufacture of the type.

An edition of 300 copies was fairly common in the 1480s, the decade during which the Josephus volume was printed by Joannes. If Joannes wore out his font of type by producing an edition of this size, then the labor expenditure for each of the 300 copies amounted to forty-seven hours.

This figure of forty-seven man-hours by no means represents the total cost of producing each copy of the book. We have ignored all overhead and editorial expense, as well as the many other outlays which occur in commercial ventures of all kinds. And, above all, we have not even mentioned the expenditures for materials—fuel, metal, ink, and, most important, paper.

Hirsch concludes that “the permissible generalization . . . is that in the earliest period the cost of material probably equalled or slightly exceeded the cost of labor, that it decreased at a slow rate, but may

TABLE III. *Labor Requirements for the Production of the Joannes-Josephus in Various Edition Sizes*

	<i>Number of Man-Hours by Size of Edition</i>			
	200	300	500	1,000
Number of impressions type is able to withstand (table I, col. <i>N</i> )	7,000	10,500	17,500	35,000
Number of man-hours required per copy for composition, presswork, and bindery work (from table II)	50	42	35	30
Number of man-hours required per copy for manufacture of type (table I, col. <i>L</i> )	8	5	3	2
Totals	58	47	38	32
Percentage of overall labor costs attributable to type manufacture	14%	11%	8%	6%

have been reduced to a third of the total cost some time during the second half of the XVI century” [22, p. 40]. Although, as Hirsch points out, this is no more than a generalization, it nevertheless indicates that the cost of furnishing the paper for, and printing, each copy of a 300-copy edition of the Joannes-Josephus must have been very high, quite likely equivalent to the earnings of a skilled printing craftsman over a period substantially greater than a full week. The retail price of the book would, of course, have been considerably more than that, for it would have had to take into account many other costs—overhead, transportation, sales expenses, allowances for bad debts, and so forth. Moreover, the businessmen who had invested their funds in the printing and selling of the book would have had to set the market price high enough to enable them to make a profit. It would thus appear that a book of the typographic characteristics and size of the Josephus must have sold for a sum equivalent to the earnings of an artisan over a period of several weeks. Even in the fifteenth century, when wages were low, this must have represented a tidy outlay on the part of the purchaser. Printed books were obviously cheaper than manuscripts, but they were still quite expensive.

It was stated earlier in this study that the best we could hope to achieve in our investigation of the durability of early type would be

to ascertain whether this type was so soft that it could provide only a few hundred to a few thousand impressions, or whether it was hard enough to allow 10,000 or more impressions be made from it.

We can, at this point, reject as untenable any assertion that early type was so fragile that only a few hundred to a few thousand impressions could be expected from it. In Table I we see that when  $N$  (the number of impressions type is able to withstand) is 1,000, an edition of only twenty-nine copies could be produced from our hypothetical font of 84,000 characters, and that  $L$  (the number of man-hours which have been spent in making this type, prorated on a per-copy basis for this edition of twenty-nine copies) would have been fifty-five hours, a forbiddingly high figure. The reader is reminded that if the edition had been large—say, 1,000 copies—the  $L$  cost would still have been fifty-five hours of labor per copy, since Joannes would have had to keep casting new type repeatedly (at the cost of 1,568 man-hours per 84,000 characters) in order to keep his pressmen working. In fact, in an edition of 1,000 copies, with a type life expectancy of only 1,000 impressions, Joannes would have been able, in theory, to print exactly 1,000 copies of each form with the type before it wore out. Since he had thirty-five forms to complete, he would have had to cast, in all,  $35 \times 84,000$  characters, or 2,940,000 pieces. This would have entailed  $35 \times 1,568$  man-hours (54,880 man-hours) simply to make the type for the printing of this one edition. If we divide the last figure by the number of copies in the edition, 1,000, we come back to our previously determined cost of fifty-five man-hours per copy for the manufacture of the type in an edition of this size. (A small offsetting factor would have been introduced under these conditions—the time for washing and distributing the type after printing each form would have been eliminated.)

We can, accordingly, assume that it would have been financially impractical for Joannes to have printed the Josephus work if type was so soft that it would yield only as few as 1,000 impressions. It also seems unlikely that the type's life expectancy was limited to as few as 7,000 impressions (permitting an edition of only 200 copies, with the cost of type manufacture running to eight man-hours per copy). I think that the information currently available to us permits us to assume that type was probably usable, on the average, for at least 10,000 to 20,000 impressions. This would have permitted edition

runs of the Joannes-Josephus of between 286 and 571 copies with labor costs for type manufacture ranging from five to three man-hours per copy (Table I). I suspect, however, that the incunable printer could normally expect that his type would last for several tens of thousands of impressions.

Above the financial considerations analyzed here, there are other grounds for believing that incunable type was moderately durable. (I use the word “moderately” to indicate that, on the one hand, the type was not so soft that it could be subjected to only a few thousand blows of the platen, while, on the other hand, it was not as durable as modern type.)

We must concede that the alloy from which the type was made had to be reasonably tough. Had the characters consisted of lead alone, they would have been very soft, of course, and would not have been able to survive as many impressions as the process of alloying made possible.<sup>9</sup> Nevertheless, it is quite feasible to produce a press run of respectable size using type characters made of nothing but pure lead. William Blades proved this more than a century ago, describing his purpose and method in these words [23, p. 108]:

The metal of which Caxton’s types were cast can only be conjectured. The probability is that it was soft, and if even so soft as lead it would have been sufficiently durable to have performed the work for the small impression required of each book. In demonstration of this, the author procured, by the kindness of Messrs. Figgins, a fount of their Caxton types in pure lead, and composed a page of Caxton’s “Chess Book,” working it in the usual way, at a common hand press, and numbering each impression as it came from the tympan in order to note its gradual wear. The paper was a royal cartridge of the common rough quality, and was worked dry. After 500 pulls, perceiving no appreciable wear, the author stopped the experiment, being sufficiently satisfied.

9. The use of an alloy, rather than lead alone, not only increases the durability of type but also provides other noteworthy advantages. The modern type alloy is made of lead, tin, and antimony, and may also include small percentages of copper and/or other metals. Its melting point is approximately 475°F, much lower than that of lead (621°F). The alloy’s fluidity is superior to that of lead, as are its expansion and contraction characteristics in the mold during the processes of cooling and solidification. Type made of lead alone will produce fewer impressions by far than type made of the alloy, and the quality of these impressions will be decidedly inferior [5, pp. 15–16].

Blades considered it likely that Caxton's type was soft. But, how soft? He says that he used a rough paper and ran it dry. The incunable printer, more often than not, also used what might be termed a rough paper, but ran it wet. The dry paper which Blades ran was, of course, harder on his type than wet paper would have been. He stopped the experiment at the 500th impression, although it is obvious that he could have printed many more sheets, had he chosen to do so. Hence, if type made of pure lead alone can yield more than 500 impressions on dry paper—and probably a number of multiples of that figure—how many more impressions could have been gotten if wet paper had been used and if the type had been cast from the much tougher alloy which we know to have been available in incunable days? The evidence provided by Blades's experiment surely establishes the *minimal* figure for incunable type durability at several thousands of impressions.

Moreover, had fifteenth-century type not been capable of withstanding many thousands of impressions, virtually every page of incunable print which has come down to us would include a distressingly large number of broken and fuzzy characters. Much of incunable printing is poorly done, it is true, and there is no shortage of pages of text in which many defective characters may be seen. It is an indisputable fact that more than a few incunable printers continued to use type long after it should have been discarded. However, if we restrict our investigation to the output of the better printers of the time, we find that the condition of the individual type characters on the pages is uniformly good. Would this be true if type was forever breaking down?

Horatio Brown, having studied the craftsmanship of the master printer Nicolaus Jenson, makes this comment [24, pp. 17–18]: “The characteristics of the Jenson type are maintained all through his work; and if we note a marked difference in the freshness and sharpness of the print of one year as compared with that of another, this is to be attributed to the fact that the more brilliant print is the result of a fresh casting from the old matrices, or possibly even from fresh matrices newly stamped from the original punches.”

Brown, it will be noted, does not say that he has found numerous cases in which individual pieces of type (or even lines or islands of type) within a page had broken down. He speaks, on the contrary, of

a uniformity of freshness and sharpness, implying that the wear which inevitably took place did so on a broad basis. Had type been breaking down after comparatively short runs of the press, such a uniformity could not have prevailed for very many impressions unless Jenson had been casting replacements for *entire* pages repeatedly—that is, every time a type breakdown occurred within those pages. If Jenson had been doing this, textual examination of specific pages from copy to copy within any edition of his would reveal the fact very quickly, and the year-to-year comparison which Brown makes would be totally inappropriate.

No printer, not even as meticulous a craftsman as Jenson, could have permitted himself the luxury of examining each sheet for defective characters as it came off the press and, if he found such characters cropping up, stop the press, take the form off the press, remove and discard the offending type, and then set up replacement type, lock it into position in the form, put the form back on the press, and start printing again. While such stoppages did occur from time to time, it would have spelled financial ruin to a printer to have been compelled to close down his press operation repeatedly during the course of each working day for the purpose of replacing worn-out type. How much more calamitous would it have been if the printer had been forced to set up an entire page when a breakdown took place in only a small portion of that page!

It seems apparent that when the incunable printer put a form on the press he must have known that the type could be expected to last for a run of quite a few thousand impressions. If, at the end of the press run of any particular form, it was noticed that certain characters were showing signs of wear, they could be culled out as the type was being distributed into the cases, so that no interruption of the press operation would be required.

An objection may be raised at this point. Reference was made earlier in this study to the assertion of Paul Manutius, in 1570, that type would wear out in only four months, and that it was desirable to cast fresh type before starting work on any new book in order to lessen the risk of having the characters go bad in the middle of the printing of the book. The inference to be drawn, it would appear, is that early type was not very durable. Such a deduction, however, is not necessarily valid.

To begin with, it is not at all unlikely that Manutius was exaggerating his difficulties with type, in which case his complaints should not be taken too seriously or too literally. He would not be the first printer, nor the last, to find fault with materials and equipment, justifiably or not. Moreover, even if the Manutius figure of four months is taken to be correct for the life expectancy of early type, we have no way of knowing how many impressions were actually made with the type during that period. How many characters were available at the start of the work? How many presses were used on the job, and how much work did they produce? How many times, in essence, did the average character print an image of itself on paper during those four months?

Finally, Haebler cites a contract, dated December 19, 1483, which may be construed as presenting a position differing radically from that of Manutius [25, p. 19]. In this document, Domenico Caraffa agrees to lease equipment and type to a printer who, according to Haebler, “was designated as Justo [T]heotonico, probably identical with the Neapolitan printer Jodocus Hohenstein.” Haebler says that the contract stipulates “that the weight of the type leased by Hohenstein for nine months at the price of 10 ducats was 122 lbs.” Haebler also deduces from other documentation that this type had in all probability already been used for eighteen months by two previous associates of Caraffa, Johann Steingamer of Landsburg and Werner Raptor of Marburg.

If a printer paid as much as ten ducats for a nine-month lease of type, at a time when the earnings of the average Italian printing craftsman for an entire month amounted to only four ducats [22, p. 38], he must surely have planned to get his money’s worth by utilizing the type rather thoroughly. In addition, this type, as has been noted, may already have seen eighteen months of use. That it was being leased instead of sold would indicate either that Caraffa did not expect it to be completely worn out when Hohenstein had finished with it, or that he simply wanted to retain ownership of the metal.

The fact remains that in both cases—Caraffa’s type and that of Manutius—we still do not know how many impressions were involved. The evidence is not conclusive, of course, but it does appear that Caraffa’s estimate of type durability, in 1483, was substantially higher than Manutius’s, in 1570.

### Conclusion

If type life expectancy during the incunable era had been limited to only a few thousand impressions, the excessive labor costs inherent in the manufacture of the type characters would have raised the production costs of the printed book very substantially. It is difficult to believe that printing could have been carried on extensively on a commercial basis during the fifteenth century had type life expectancy been very low. Moreover, the fact that we do not find large numbers of defective characters in the works of the better printers of the time tends to reinforce this point of view, as does the prevalence of the "freshness and sharpness of the print of one year as compared with that of another," pointed out in the works of Jenson by Brown.

Still another indication that incunable type was sturdy enough to last for quite a few thousand impressions is furnished by Blades's experiment with type made of pure lead.

The lines of reasoning which have been pursued in this study lead to the conclusion that incunable type was fairly durable, probably to a substantially greater degree than has been suggested by either the British Museum Catalogue or Febvre and Martin. It would appear that the number of "acceptable" impressions which the early printer could expect to obtain from his type must have been on the order of several tens of thousands.

### REFERENCES

1. Audin, Maurice. *Les types lyonnais primitifs conservés au Département des Imprimés*. Paris: Bibliothèque nationale, 1955.
2. Febvre, L., and Martin, H.-J. *L'apparition du livre*. Paris: Éditions Albin-Michel, 1958.
3. Bühler, Curt F. *The Fifteenth-Century Book: The Scribes, the Printers, the Decorators*. Philadelphia: University of Pennsylvania, 1960.
4. Audin, Maurice. "Types du XV<sup>e</sup> siècle." *Gutenberg-Jahrbuch* (1954), pp. 84-100.
5. Jackson, Hartley E. *26 Lead Soldiers*. Stanford, Calif.: Stanford University Press, 1937.
6. Kubler, George A. *The Era of Charles Mahon, Third Earl of Stanhope: Stereotyper, 1750-1825*. New York: J. J. Little & Ives, 1938.
7. British Museum, Department of Printed Books. *Catalogue of Books Printed in the XVth Century Now in the British Museum*. Pts. 1-9. London: Trustees of the British Museum, 1908-62. Lithographic reprint, 1963.
8. Didot, Ambroise Firmin, *Alde Manuce et l'hellénisme à Venise*. Paris: A. Firmin-Didot, 1875. Cited by Febvre and Martin (see [2, p. 74] above).

9. Pollak, Michael. "Production Costs in Fifteenth-Century Printing." *Library Quarterly* 39 (October 1969): 318-30.
10. Goff, Frederick R., ed. *Incunabula in American Libraries*. New York: Bibliographical Society of America, 1964.
11. Biringuccio, Vannoccio. *The Pirotechnia*. Translated by Martha Teach Gnudi and Cyril Stanley Smith. New York: American Institute of Mining and Metallurgical Engineers, 1942.
12. *An Account of Calligraphy and Printing in the Sixteenth Century*. From dialogues attributed to Christopher Plantin. Printed and published by Plantin at Antwerp in 1567. Translated by Ray Nash. Cambridge, Mass.: Department of Printing and Graphic Arts, Harvard College Library, 1940.
13. Moxon, Joseph. *Mechanick Exercises on the Whole Art of Printing, 1683-84*. Edited by Herbert Davis and Harry Carter. London: Oxford University Press, 1958.
14. Voet, L. "The Making of Books in the Renaissance as Told by the Archives of the Plantin-Moretus Museum." *Printing and Graphic Arts* 10, no. 2 (December 1965): 33-62.
15. *Correspondance de Christophe Plantin*. 9 vols. Antwerp: J. E. Buschmann, 1883-1918.
16. Vervliet, H. D. *Sixteenth Century Printing Types of the Low Countries*. Translated by Harry Carter. Amsterdam: Menno Hertzberger & Co., 1968.
17. Oswald, John Clyde. *A History of Printing*. New York: D. Appleton & Co., 1928.
18. *Short-title Catalogue of Books Printed in Italy and of Italian Books Printed in Other Countries from 1465 to 1600 Now in the British Museum*. London: Trustees of the British Museum, 1958.
19. Carter, Harry. *A View of Early Typography Up to About 1600*. Oxford: Clarendon Press, 1969.
20. Legros, Lucien Alphonse, and Grant, John Cameron. *Typographical Printing-Surfaces*. London: Longmans, Green & Co., 1916.
21. A. B. "The Art of Cutting, Casting, and Preparing of Letters for Printing." *Universal Magazine*, vol. 6 (1750). London: Published for J. Hinton, 1747-1815. Cited by Rollo G. Silver in *Typefounders in America, 1787-1825*. Charlottesville: University Press of Virginia, 1965.
22. Hirsch, Rudolph. *Printing, Selling, and Reading, 1450-1550*. Wiesbaden: Otto Harrassowitz, 1967.
23. Blades, William. *The Biography and Typography of William Caxton, England's First Printer*. 2d ed. London: Trübner & Co., 1882.
24. Brown, Horatio R. F. *The Venetian Printing Press, 1469-1800*. London: J. C. Nimmo, 1891.
25. Haebler, Konrad. "Typefounding and Commerce in Type during the Early Years of Printing." *Ars Typographica* 3 (July 1926): 3-35.

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# Résumé des Articles

Traduction : Fernand Baudin

Les aspects linguistiques dans l'espace d'un manuscrit *par Virginia J. Cyrus*

Alors que les formes des lettres y sont très régulières, on remarque dans les manuscrits anglo-saxons de nombreux écarts dans les espacements, leurs emplacements et leurs encombrements. En examinant l'*Orose* du Roi Alfred, dans le manuscrit Tollemache, l'auteur a observé que les espacements marquent des rythmes visuels et qu'ils correspondent en fait à des éléments linguistiques tels que la construction grammaticale — comme le révèle une simple analyse. Ce manuscrit fournit ainsi la preuve matérielle qu'il y a dans l'anglo-saxon des éléments de nature non segmentaire dont on ne pouvait qu'inférer l'existence précédemment.

L'emploi du trait d'union pour marquer les coupures de mots *par F. M. O'Hara, Jr.*

Les moyens fantaisistes utilisés par les prototypographes pour indiquer les coupures de mots, incitèrent l'auteur à étudier les manuscrits et les incunables, en original et en facsimilé. Il découvrit ainsi que l'expression typographique du trait d'union s'était standardisée progressivement, que les usages arbitraires des lettrés le cédèrent à la division phonétique, et que l'usage du trait d'union pour indiquer les coupures s'est lentement généralisé. Cette évolution fut encore perturbée au cours du XVI<sup>e</sup> siècle et ce n'est qu'à la fin du XVII<sup>e</sup> siècle que se fixèrent définitivement les usages que nous appliquons couramment.

La lecture automatique des imprimés *par Donald E. Troxel*

L'objet principal de l'article est d'examiner la lecture automatique des imprimés et le système de codes qu'elle produit en vue du traitement ultérieur qui en permet la lecture en Braille II, en langage épelé ou en langage courant. Il décrit diverses techniques de recherches qui tendent à déterminer automatiquement les seuils de différenciation des corps de caractères, des styles, des justifications et des ponctuations. Comme le produit de la lectrice pour aveugles est destiné à l'usage direct de l'homme et non d'une autre machine, les instructions à lui donner devaient tenir compte d'une vitesse de lecture à peu près égale au débit normal de la voix et du fait que la lectrice devait autant que possible commettre moins d'erreurs qu'un lecteur humain. La vitesse atteinte fut de 75 mots-minute, ce qui est inférieur à la vitesse requise. Le taux d'erreurs permises, en revanche, fut respecté : il ne dépassa pas 07 %.

La vocalisation dans la lecture silencieuse *par Donald L. Cleland*

On discute depuis longtemps sur le point de savoir si la vocalisation doit être surmontée, encouragée, ou simplement tolérée au cours de la lecture silencieuse. Les expériences passées sont analysées. Une expérience récente est décrite au cours de laquelle on tenta de déterminer l'incidence de cette vocalisation dans deux groupes d'élèves du secondaire : d'une part les bons élèves, d'autre part des attardés.

Conclusion : la vocalisation est une donnée naturelle dans le processus de lecture ; aux moments voulus nous y avons tous recours en tant que renforcement sensoriel secondaire.

La résistance des caractères typographiques du XV<sup>e</sup> siècle *par Michael Pollak*

En étudiant les allusions qu'il a trouvées aux usages primitifs de la fonderie et de la composition, l'auteur a calculé le temps nécessaire au XV<sup>e</sup> siècle pour "couler en moule" un millier de signes. Il estime qu'il fallait quatorze heures de main d'oeuvre. Afin de déterminer ensuite le degré de résistance de ces caractères à l'usure des opérations de composition, d'impression, de lavage et de distribution, il applique les données obtenues à l'édition d'un Flavius Josephus imprimé à Venise en 1486 et qui suppose plusieurs tirages de quantités variables. Posant en fait qu'un taux de main d'oeuvre trop élevé aurait rendu ce livre, ainsi que ses semblables, invendable, il arrive à la conclusion que les caractères des incunables pouvaient subir 10.000 à 20.000 tirages — tout en donnant à entendre que les imprimeurs contemporains en attendaient sûrement beaucoup plus. L'auteur ne manque pas de citer d'autres preuves à l'appui de sa thèse concernant l'excellence des caractères primitifs.

## Kurzfassung der Beiträge

Übersetzung: Dirk Wendt

Linguistische Merkmale der Buchstabenzwischenräume bei Kopisten  
*von Virginia J. Cyrus*

Im Gegensatz zu der Regelmäßigkeit der Buchstabenformen in handgeschriebenen altenglischen Manuskripten zeigen die Buchstabenzwischenräume in Größe und Anordnung große Variation. Untersuchungen der Zwischenräume im Tollemache-Manuskript von Alfred's *Orosius* ergeben umfassende systematische Anordnungen, von denen gezeigt werden kann, daß sie linguistischen Merkmalen des Textes wie syntaktischen Strukturen entsprechen, die durch unmittelbare Analyse ihrer Komponenten erkannt werden können. So belegt das Manuskript in der Graphik nicht-segmentäre Merkmale der Sprache, die sonst nur indirekt erschlossen werden könnten.

Der Gebrauch des Bindestrichs im Druck zur Kennzeichnung geteilter Wörter  
*von F. M. O'Hara, Jr.*

Die unsystematische Anwendung der Worttrennung bei den frühen Druckern führte den Verfasser zur Untersuchung von Inkunabeln und Reproduktionen von Manuskripten und Wiegendrucken. Diese Studien zeigen eine allmähliche Standardisierung der typographischen Form des Bindestrichs, eine Entwicklung

der phonetischen Worttrennung nach akademischen Regeln, und eine langsame Entwicklung des allgemeinen Gebrauchs des Bindestrichs zur Kennzeichnung geteilter Wörter. Diese Tendenzen kehren sich während des sechzehnten Jahrhunderts um, und erst im ausgehenden siebzehnten Jahrhundert entstehen allgemein Worttrennungspraktiken, wie wir sie heute kennen.

#### Automatisiertes Lesen einer gedruckten Seite von *Donald E. Troxel*

Dieser Aufsatz handelt hauptsächlich vom automatisierten Lesen einer gedruckten Seite, sodaß eine Folge von Zeichen entsteht, die so weiterverarbeitet werden kann, daß die Information einem Blinden in Form der englischen Braille-Blindenschrift Stufe 2 (entspricht der deutschen Blinden-Anfangskurzschrift, Anm.d.Übers.), in gesprochener Sprache oder in synthetischer Sprache zugänglich gemacht werden kann. Es werden Heuristiken für automatische Schwellenbestimmungen, Schriftgradbestimmungen, Zeilen- und Zeichen-Eingabe, das Abfühlen von Konturen und das Erkennen von Punctuation und Symbolen beschrieben. Da die Ausgabe der Lesemaschine für Blinde direkt vom Menschen aufgenommen werden soll, ist der Seiten-Leser so angelegt, daß die Geschwindigkeit ungefähr normaler Lesegeschwindigkeit entspricht und daß die Lesemaschine etwas weniger Fehler macht, als ein menschlicher Leser machen würde. Die tatsächlich erreichte Lesegeschwindigkeit war etwa 75 Wörter pro Minute, was nicht ganz die Geschwindigkeitsanforderung erfüllt. Der Fehler-Anteil genügte jedoch mit 0.7 Prozent beobachteten Fehlern den Anforderungen.

#### Vokalisation beim stillen Lesen von *Donald L. Cleland*

Es gibt eine langandauernde Kontroverse darüber, ob Vokalisationen beim stillen Lesen underdrückt, gefördert, oder nur eben geduldet werden sollten. Frühere Experimente werden diskutiert. Hier wird über eine Untersuchung berichtet, in der das Auftreten von Vokalisationen beim stillen Lesen bei zwei Gruppen von Kindern der Mittelstufe festgestellt wird: Lese-Fertige und Lese-Gehemmte. Die allgemeine Schlußfolgerung ist, daß die Vokalisation eine natürliche Begleiterscheinung des Lese-Vorganges ist, und daß wir alle sie gelegentlich als sekundäre Bekräftigung benötigen.

#### Die Haltbarkeit von Lettern aus dem XV. Jahrhundert von *Michael Pollak*

Aus einer Übersicht von Unterlagen über frühe Schriftguß- und Satzpraktiken errechnet der Verfasser die Arbeitszeit, die erforderlich war, mit der Hand im XV. Jahrhundert 1000 Lettern zu gießen, und gelangt zu einer Zahl von vierzehn Arbeitsstunden. Um die Widerstandsfähigkeit der Lettern gegen Abnutzung in der Druckpresse, beim Setzen, Reinigen und Ablegen zu ermitteln, wendet er diese Arbeitskosten auf die Publikation eines Buches im XV. Jahrhundert an, der Werke von Flavius Josephus, gedruckt 1486 in Venedig, wobei er verschiedene hohe Auflagen annimmt. Unter der Annahme, daß übermäßige Arbeitskosten pro Exemplar dieser Produktion dieses Buches und anderer ähnlicher Bücher unwirtschaftlich gemacht hätte, schließt er, daß die Wiegendrucklettern mindestens 10 000 bis 20 000 Abzüge aushielten, vermutet aber, daß ihre tatsächliche Lebenserwartung viel höher war. Er ergänzt seine Kostenanalyse durch Zitate anderer Belege, um zu zeigen, daß die Wiegendrucklettern recht haltbar waren.

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