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Abstract

Three-linguistically-motivated algorithms for assigning between-word space sizes were compared for their impact on text readability: a computer-implemented heuristic analysis assigned extra spaces between word groups corresponding to major phrases; a phrase-structure analysis assigned each space a size proportional to the depth of the phrase structure at that point; a prosodic analysis assigned space sizes proportional to the between-word pauses indicated if the sentences were spoken; finally, an even-spacing algorithm, assigned a constant amount of space between each word on a line. The readability of the formats were contrasted using the Cook-Chapman find-the-odd-word test in a paragraph version. The readability results showed the following significant ordering of increasing difficulty: heuristic—>phrase-structure=prosodic=even-spaced. The reason that spacing based on the heuristic parser results in better comprehension than based on the complete phrase structure may be that good readers guide their eye movements by a similarly crude initial parse of texts. These results suggest that the readability of text can be improved with the aid of a rudimentary automatic parser.

We started to suit down a sew in our first yard b
it up because our hammers were no good. Jack n
is always bumping his toes and falling over things.
The farmer said we could have two quarts of milk
we would have to bring a couple of bags to put the
a sweet tooth. They like sweet things, put lots of salt
for the same reason. John did his work so well an
year that his teacher thought he would be sure to
and takes along a big pail of lemonade it is very up
left the pencils at home. The old teacher was crue
made mistakes, so when he left all the boys were sa
of dirty shoes on the floor and all over the nice cl
careful the children had been. When the little boy
by a car we were afraid he might never be able t
and the rain began to fall, Mr. Jones went back to h
did not want to get sunburned. One day we rented
caught enough we went back to the house where we
dinner. The poor people of Holland wear heavy woo

Spacing Printed Text to Isolate
Major Phrases Improves Readability

Thomas G. Bever, Steven Jandreau,
Rebecca Burwell, Ron Kaplan &
Annie Zaenen

It is intuitively clear that text is easier to read if it is formatted with linguistic structure in mind. Over the past two millenia, the development of phonemic alphabets has involved a consistent trend to reveal more of the surface phrase structure in the way text is printed: the introduction of spaces between words, special characters to begin and end sentences, the comma, and the addition of extra space after a period and comma, have all contributed to a representation of the prosodic segmentation which sentences would have when spoken. These developments are of both practical and theoretical significance. Practically, they suggest that reading performance can be improved by using a more complete reflection of linguistic structure in printing: theoretically, they suggest that certain kinds of prosodic information are important aids to normal sentence comprehension.

Various authors have suggested that linguistic structure could be advantageously reflected in the physical characteristics of print, rather than through the introduction of new types of punctuation marks (Bower and Bever, 1974). For example, various studies have shown that if propositions are arranged on separate lines, comprehension is improved in the general reading population (Miller and Anglin, 1979). A consistent line of research has shown that people with good vocabulary but with reading disabilities, read text normally if it is printed with extra spaces between propositions (Cromer, 1970). Cromer argues that the nature of much reading disability is a specific deficit in the use of segmentation strategies which group together words which are likely to be in the same proposition: providing extra spaces around propositions makes up for this deficit.

In our review of the literature, which we limited to studies done in English (see References), we found 24 distinct experiments on the effect on text readability of formats that separate phrases, compared to more traditional formats. Of the 12 studies which assess reading comprehension or verbatim recall,

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all report an improvement in the phrase-marked format (with a subject-weighted mean of +12.7 percent compared to a normal format for the 10 significant studies.) Of the 12 studies which recorded reading rates, 8 reported increased reading speed in the phrase-marked format (with a subject-weighted mean of +9.9 percent for the 6 significant studies).

Most of the previous research has used linguistic analysis imposed by hand, often based on relatively untutored intuitions about where phrases begin and end. Recently, Frase and Schwartz (1979) and Jandreau et al (1986) used simple structure-assigning algorithms which were implemented in computer programs. Frase and Schwartz's program identifies markers which are likely to signal the boundaries of propositions (conjunctions, punctuation marks, and so on): they showed that arranging propositions identified in this way on separate lines lead to better reading performance. Jandreau et al used a program, "cyclephrase," to identify major phrases (it is basically an ATN sensitive to a few hundred function morphemes—we describe it in more detail below). They found that adding extra space between major constituents identified in this way improved reading performance significantly.

These results suggest that enriching the amount of linguistic information about phrases in printed text can improve readability. But the previous studies have not implemented a complete linguistic phrase analysis of any kind. The present study contrasted three kinds of linguistically based information: a hand constructed phrase structure analysis, a prosodic-phrase analysis (Selkirk, 1982) and a "phrasetree" analysis adapted from "cyclephrase" used in Jandreau et al.

The phrase structure analysis involved assignment of a surface constitutent structure, motivated largely within the context of lexical-functional grammar. The prosodic analysis had as input the phrase structure analyzed text. We used an implementation of Selkirk's rules for prosody, which operate on a combination of lexical and phrase structure information, to assign relative between-word pause durations in a spoken version of the text. The phrasetree analysis was done by the program, "phrasetree," which is an extremely simple tree structure-assigning algorithm—it uses less than 300 lines of code, and in its original version ran satisfactorily on a TRS-80 Model II computer. It recognizes about 270 function words, grouped into about twenty conventional classes (preposition, deter-

miner, etc.): content words are not identified. The essential algorithm takes in a sentence (defined by puntuation), and breaks the sentence into two parts near the center: it uses an ordered set of patterns to impose the breaks, first searching for conjunctions, then for particular kinds of pair sequences of word types. The algorithm iterates on each of the two parts of the sentences (hence, the original name "cyclephrase"), until phrases less than three words in length are defined. The output is an unlabelled tree structure.

The purpose of our experiment, therefore, was to examine the effects of these three different ways of spacing text upon readers' comprehension.

Method

Materials

The Cook-Chapman find-the-odd-word test was printed in each of these three ways (see figures 1, 2 and 3), together with an even-space control condition. This text has been used as a standard in the printing industry to assess the readability of different fonts and page format styles (Coleman and Kim, 1961). Subjects read 26-35 word paragraphs each with a word that did not make sense in the context. One such paragraph with the odd word in italic is shown below:

> We worked all day in the shop making a chair. When night came it was nearly done and to finish it we needed only one small piece of *glass*.

The subjects' task is to strike out the odd word in each paragraph. The test is time-limited, so the number of paragraphs a subject gets through is a measure of the readability of the text. There are two paragraph sets, each with 25 paragraphs. One set is intrinsically harder and is given after the other set to counteract for any practice effect. The standard technique is to present the first text in one format style, and the second in another: this gives a basis for comparing each subject on two formats. As is standard in the use of the test for assessing formats, the short paragraphs in each group were run together into one large paragraph, with a special mark indicating the beginning of the next story.

We adapted the test so that there were eight experimental versions. The first set was always formated in the standard right-ragged manner, with equal sized spaces on each line (note that the average size of the space on each line varied somewhat according to how many words filled it.) The second subtest

was formated in accord with one of four algorithms described below. In each of the following cases, the space size was varied according to one of the linguistic algorithms described previously. In each case, the average space size on each line was the same as in the corresponding lines in condition four below, the equal condition. That is, the space sizes were varied by adding and subtracting fractional amounts of space from the equal-spaced format condition. The four versions were thus:

1 Phrasetree controlled. The space following each major constituent identified by phrasetree was varied proportionally according to the number of words in that constituent.

2 Phrase-structure controlled. Each space after a word was varied according to the number of constitutents that ended at the word.

3 Prosody controlled. Each space after a word was varied according to the indicated pause length for that position.

Figure 1
Phrasetree format, large spacing, second materials set.

We started to cut down a tree in our front yard   but after working for two hours   we gave it up   because our hammers were no good. * Jack never seems to look where he is going and is always bumping his toes and falling over things.   I think anyone who does that is rather smart. * The farmer said we could have   two quarts of milk   and a quart of cream tomorrow   but we would have to bring a couple of bags to put them in. * Some people have what is called a sweet tooth.   They like sweet things, put lots of salt in their coffee   and often eat candies for the same reason. * John did his work so well   and got such good grades   during the whole year   that his teacher thought he would be sure   to fail the test. * When one goes on a picnic and takes along a big pail   of lemonade it is very upsetting to find   out that someone has left the pencils at home. * The old teacher was cruel to the boys   and beat them when they made mistakes,   so when he left all the boys were sad. * When my mother saw the marks of dirty shoes on the floor   and all over the nice clean beds,   she was surprised to see how careful the children had been. * When the little boy next door had both of his legs broken by a car we were afraid   he might never be able   to see again. * When it began to get cloudy and the rain began to fall,   Mr. Jones went back to his home for his umbrella   because he did not want to get sunburned. * One day we rented a boat and went fishing. After we had caught enough we went back to the house where we cooked the chickens   and had them for dinner. * The poor people of Holland wear heavy wooden shoes and as they walk the sound of their shoes makes   it very quiet in the streets. * The other day we forgot all about our little kitten   and were gone all day.   When we returned, we found him on the back porch barking to be let in. # We are interested in what is happening in America   and the other great nations of the world,   so each morning we read   the comics with great care. * The river was so wide and the current so strong that we always kept a boat with oars   and a sail ready for use   whenever we wanted to walk across. * Mary said she mailed a letter   to me at the postoffice yesterday, but the milkman did not leave anything for me   when he came this morning. * In order to be sure to have enough food   to last them through the cold winter,   the settlers planted large fields of rocks in the fertile land of the valley. * John is going to town with his mother to buy a new suit,   for he is going to a party tomorrow where everybody must appear in their worst clothes. * When the house caught fire one of us called the fire department,   and in less than five minutes the policemen were hard   at work putting it out. * Frank hopes to be a great baseball player when he grows up. He plays all the time and never goes out in the afternoon   without taking his cane with him. * On rainy afternoons we have fun   by cutting things out of paper and cardboard.   Dolls and soldiers and even playhouses can be easily made with a pair of pants. * There was a great deal of rain and wetness in that country,   so the poor people who lived there could grow   no plants because of the dryness of the land. * In order to make the garden in the front of our house   more beautiful we were careful   to plant many weeds there.   We worked all day in the shop making a chair.   When night came it was nearly done,   and to finish it we needed only   one small piece of glass. * We were out in the middle of the water,   everywhere we could see nothing   but big waves, except when a train passed close to us,   going in the opposite direction. * One hot afternoon this summer we all got so thirsty   that we sent one of the children down   to the nearby river to get a big pail of stones. * People put grease on the wheels   of their wagons to make them turn more easily, so we never drive   without having a can of sand ready for use.

4 Equal-spacing. This is the same standard formatting as for the first set. For every one of the three preceding conditions there was a corresponding even-spaced formatted version, with the same line lengths and the same average space size.

The experimental materials were varied with two degrees of variation in space size. In the "large" variation condition, the space size could be as large as 2.5 full spaces; in the "small" variation condition, the space size could be as large as 1.75 full spaces. (Figures 1-3 are examples of the materials used.)

Subjects
Subjects were eighty undergraduates at Monroe Community College, Rochester, New York, who volunteered for paid participation. Subjects were recruited from six different courses. In each course, we randomly distributed an equal (or

Figure 2
Phrase-structure format, large spacing, second materials set.

We started to cut down a tree in our front yard   but after working for two hours   we gave it up because our hammers were no good. ✦ Jack never seems to look where he is going   and is always bumping his toes and falling over things. I think anyone who does that is rather smart. ✦ The farmer said we could have two quarts of milk and a quart of cream   tomorrow   but we would have to bring a couple of bags to put them in. ✦ Some people have what is called a sweet tooth. They like sweet things, put lots of salt in their coffee and often eat candies for the same reason. ✦ John did his work so well and got such good grades during the whole year that his teacher thought he would be sure to fail the test. ✦ When one goes on a picnic and takes along a big pail of lemonade   it is very upsetting to find out that someone has left the pencils at home. ✦ The old teacher was cruel to the boys and beat them when they made mistakes,   so when he left all the boys were sad. ✦ When my mother saw the marks of dirty shoes on the floor and all over the nice clean beds,   she was surprised to see how careful the children had been. ✦ When the little boy next door had both of his legs broken by a car   we were afraid he might never be able to see again. ✦ When it began to get cloudy and the rain began to fall   Mr. Jones went back to his home for his umbrella because he did not want to get sunburned. ✦ One day we rented a boat and went fishing. After we had caught enough we went back to the house where we cooked the chickens and had them for dinner. ✦ The poor people of Holland wear heavy wooden shoes and as they walk the sound of their shoes makes it very quiet in the streets. ✦ The other day we forgot all about our little kitten   and were gone all day. When we returned, we found him on the back porch barking to be let in. ✦ We are interested in what is happening in America and the other great nations of the world,   so each morning we read the comics with great care. ✦ The river was so wide and the current so strong that we always kept a boat with oars and a sail   ready for use whenever we wanted to walk across. ✦ Mary said she mailed a letter to me at the postoffice yesterday, but the milkman did not leave anything for me when he came this morning. ✦ In order to be sure to have enough food to last them through the cold winter,   the settlers planted large fields of rocks in the fertile land of the valley. ✦ John is going to town with his mother to buy a new suit,   for he is going to a party tomorrow where everybody must appear in their worst clothes. ✦ When the house caught fire   one of us called the fire department,   and in less than five minutes the policemen were hard at work putting it out. ✦ Frank hopes to be a great baseball player   when he grows up. He plays all the time and never goes out in the afternoon without taking his cane with him. ✦ On rainy afternoons we have fun by cutting things out of paper and cardboard. Dolls and soldiers and even playhouses can be easily made with a pair of pants. ✦ There was a great deal of rain and wetness in that country, so the poor people who lived there   could grow no plants because of the dryness of the land. ✦ In order to make the garden in the front of our house   more beautiful   we were careful to plant many weeds there. We worked all day in the shop making a chair. When night came it was nearly done, and to finish it we needed only one small piece of glass. ✦ We were out in the middle of the water,   everywhere we could see nothing but big waves,   except when a train passed close to us,   going in the opposite direction. ✦ One hot afternoon this summer we all got so thirsty that we sent one of the children   down to the nearby river to get a big pail of stones. ✦ People put grease on the wheels of their wagons   to make them turn more easily, so we never drive without having a can of sand ready for use.

nearly equal) number of each version. We do not have exact information on their reading ability, because most of the students do not know their verbal SAT scores, given that they took the test at all. The Monroe Community College must admit anyone with a high school diploma who applies: their performance on the test suggested a median SAT score around 450.

Procedure

Subjects were run in groups of 6 to 19. They were instructed in the use of the Cook-Chapman test using the standard printed instructions that come with the test, printed in a rag-ged right format with much smaller print than the actual test (this was to avoid giving them pre-training on a paticular format). Subjects read the first set (always even-spaced), crossed out all the odd words they could in the time allotted

Figure 3
Prosodic format, large spacing, second materials set.

We started to cut down a tree in our front yard but after working for two hours we gave it up because our hammers were no good. # Jack never seems to look where he is going and is always bumping his toes and falling over things. I think anyone who does that is rather smart. # The farmer said we could have two quarts of milk and a quart of cream tomorrow but we would have to bring a couple of bags to put them in. # Some people have what is called a sweet tooth. They like sweet things, put lots of salt in their coffee and often eat candies for the same reason. # John did his work so well and got such good grades during the whole year that his teacher thought he would be sure to fail the test. # When one goes on a picnic and takes along a big pail of lemonade it is very upsetting to find out that someone has left the pencils at home. # The old teacher was cruel to the boys and beat them when they made mistakes, so when he left all the boys were sad. # When my mother saw the marks of dirty shoes on the floor and all over the nice clean beds, she was surprised to see how careful the children had been. # When the little boy next door had both of his legs broken by a car we were afraid he might never be able to see again. # When it began to get cloudy and the rain began to fall Mr. Jones went back to his home for his umbrella because he did not want to get sunburned. # One day we rented a boat and went fishing. After we had caught enough we went back to the house where we cooked the chickens and had them for dinner. # The poor people of Holland wear heavy wooden shoes and as they walk the sound of their shoes makes it very quiet in the streets. # The other day we forgot all about our little kitten and were gone all day. When we returned, we found him on the back porch barking to be let in. # We are interested in what is happening in America and the other great nations of the world, so each morning we read the comics with great care. # The river was so wide and the current so strong that we always kept a boat with oars and a sail ready for use whenever we wanted to walk across. # Mary said she mailed a letter to me at the postoffice yesterday, but the milkman did not leave anything for me when he came this morning. # In order to be sure to have enough food to last them through the cold winter, the settlers planted large fields of rocks in the fertile land of the valley. # John is going to town with his mother to buy a new suit, for he is going to a party tomorrow where everybody must appear in their worst clothes. # When the house caught fire one of us called the fire department, and in less than five minutes the policemen were hard at work putting it out. # Frank hopes to be a great baseball player when he grows up. He plays all the time and never goes out in the afternoon without taking his cane with him. # On rainy afternoons we have fun by cutting things out of paper and cardboard. Dolls and soldiers and even playhouses can be easily made with a pair of pants. # There was a great deal of rain and wetness in that country, so the poor people who lived there could grow no plants because of the dryness of the land. # In order to make the garden in the front of our house more beautiful we were careful to plant many weeds there. We worked all day in the shop making a chair. When night came it was nearly done, and to finish it we needed only one small piece of glass. # We were out in the middle of the water, everywhere we could see nothing but big waves, except when a train passed close to us, going in the opposite direction. # One hot afternoon this summer we all got so thirsty that we sent one of the children down to the nearby river to get a big pail of stones. # People put grease on the wheels of their wagons to make them turn more easily, so we never drive without having a can of sand ready for use.

(our pretest with this population indicated that allowing two
and one-half minutes for each sub-test would give a suitable
range of performance.) They then did the same on the second
experimental test.

Results

Subjects' performance on each set was scored in terms of
the number of words he or she read. This number was calcu-
lated by counting the number of words to the critical word in
each passage. The measure of format difficulty we used was
the difference in the score on the standard even-spaced format
subjects read first, and the experimental format they read
second. Table 1 presents the results for each condition ex-
pressed as percentage improvement. As expected, there was
little improvement in the readability of the second set of even-
spaced materials. The greatest numerical advantage was for the
phrasereed materials, the next greatest for the phrase-structure
materials and there was no advantage for the prosodic materi-
als. Since there was no obvious effect nor any interaction in-
volving the magnitude of the space variation, we collapsed
across magnitude for specific significance tests. They showed
that the phrasetree materials are read significantly better than
the even-spaced format (X-square= 3.96 p<.05, by subject),
better than phrase-structure format (X-square=5.22, p<.025)
and better than the prosodic materials (X-square=8.29 p<.01).

Strictly speaking, the design of the Cook-Chapman materials
requires that one look only at the number of subjects who
show an improvement on a particular format. This equaliza-
tion is reflected in the fact that 50 percent of the subjects
performed better (and 50 percent performed worse) on the
second sub-test when it was in the even-spaced condition, a
substantial confirmation of its beneficial effect.

Table 1	Magnification in percent			Percent of Ss who showed gain on second test
	Small	Large	Mean	
Even-spaced	7.5	1.0	4.3	50.0
Phrasetree	13.0	15.0	14.0	80.0
Phrase-structure	1.5	8.0	4.8	45.0
Prosodic	4.3	-4.3	0.0	35.0

Table 2 | **Percent Improvement by Group and Format Condition**

|	*Low*	*High*
Even-spaced	+ 9.97	+5.29
Phrasetree	+37.43	+5.67
Phrase-structure	+11.81	-0.27
Prosodic	+ 1.59	-4.29

Previous research had suggested that subjects who are most helped by linguistic formats tend to be poor readers (Cromer, 1975; Jandreau et al, 1985, see also Muncer and Bever, 1984). Although we did not have access to independent tests of the reading ability of our subjects, we used their performance on the initial set of sentences as a relative measure of reading skill. We examined their improvement in performance on the second set against their performance on the initial set. Table 2 presents the data for the subjects who scored in the top (*high*) and bottom (*low*) 40 percent on the first text set. (We examine the lowest and highest 40 percent because it turned out that this gave us groups whose initial performance was comparable in the different experimental conditions.) The relative improvement caused by the phrasetree materials for the *low* readers is considerably greater than for the *high* subjects.

We performed an ANOVA in the difference scores for the low and high subjects. The results are shown in figure 4. Using planned comparisons among the low group, the phrasetree condition was significantly better than the even spaced condition ($p < .05$), while the other two formats were not significantly different. There were no significant differences in the high group.

Discussion

The study confirms the finding of Jandreau et al that the phrasetreed materials are read more efficiently than standard right-ragged format. However, neither the phrase-structure based treament nor the prosody-based treatment resulted in any significant improvement, unlike the phrasetree treatment. This is surprising, since prima facie the reason that phrasetree is effective at all, is because it approximates a realistic reflex of linguistic structure, either phrase structure directly, or as indirectly expressed in prosodic structure. The major visual feature

Figure 4

Scores by Group

Difference Scores

■ Low
▨ High

Format Conditions
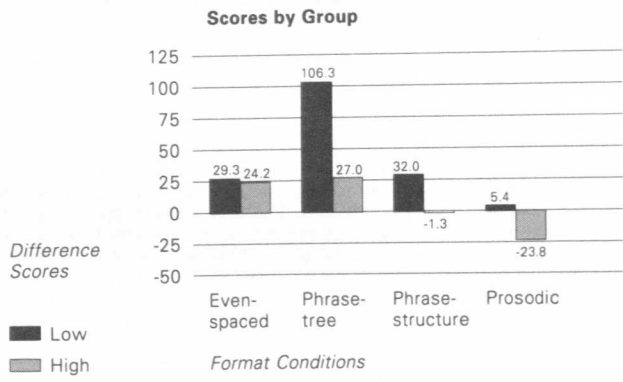
of phrasetree is that individual constituents are isolated by relatively large spaces: the major feature of the phrase-structure and prosodic structure formats is that the constituents are separated by gradations. The preliminary implications of our study is that clear separation of major constituents is of greater value than continuously varying separation. It is further striking that the prosody materials actually came close to making the text less readable than normal. There are several possible reasons for this. First, Selkirk's rules or our adaptation of them may be wrong; second, it may be the case that the prosodic information actually slows subjects down because it evokes auditory processing strategies, which reading can obviate.

This study and others demonstrate that isolating major phrases within extra spaces faciltiates reading, especially among poor readers. The implications of these results suggest that the value of an automatic analysis of linguistic structure for formatting is to isolate the major phrases of sentences. Phrasetree and other simple algorithms can approximate this, but fail in some cases. Accordingly, we expect that refined improvements in the readability of text will be possible with the use of a more powerful parser than phrasetree.

Research Summary of Reading Speed and Comprehension or Recall

Reading Speed Significant Studies		Phrase	Non-Phrase	Λ%	Ss	Design	Ph. Size	Sp. Size
Bever et al	a.	431.0	393.0	+ 9.4	40	B	L	1-3
	(b.	398.0	325.0	+22.5)				
Frase & Schwartz (1979)	3	22.7	27.7	+18.0	16	W	S	lines
	2	20.8	23.7	+15.0	16	W	S	lines
	1	18.6	21.3	+12.6	8	W	S	lines
Hartley (1980)		12.3	14.17	+16.3	18	B	L	lines
		15.0	17.5	+14.3	12	B	L	lines
Jandreau et al (1986)	1	403.0	347.0	+16.1	36	B	L	1-3
Jandreau et al (1986)	2	465.0	388.0	+19.7	44	B	L&S	1-3
Mason & Kimball (1979)		62.0	42.0	- 48.0	22	B	L	line
North & Jenkins (1951)		8.55	7.55	+13.2	120	B	S	1

Nonsignificant Studies

		Phrase	Non-Phrase	Λ%	Ss	Design	Ph. Size	Sp. Size
Carver (1970)		54.0	49.0	-12.3	18	W	S	>4
Coleman & Kim (1961)		261.2	260.0	+ 1.2	64	W	S	1
Keenan (1984)		15.8	18.9	- 16.0	24	B	S	lines
Klare et al (1957)		7.8	7.5	- 3.6	214	B	S	>4
Taylor, Wade & Yekovich	a.	31.0	30.0	+ 3.3	22	B	L	line
(1985)	b.	76.0	74.0	+ 2.7				

Comprehension and/or Recall Significant Studies

		Phrase	Non-Phrase	Λ%	Ss	Design	Ph. Size	Sp. Size
Anglin & Miller (1968)		53.0	42.0	+26.0	12	W	L	line
Brozo et al. (1983)		17.5	16.8	+ 4.0	58	B	S	slash
Cromer (1970)		59.0	45.0	+14.0	64	W	L	~3
		50.4	22.4	+28.0)	30	W	?	?
Gerrell & Mason (1983)		72.3	66.0	+ 9.5	32	W	S	line
Graf & Torrey (1966)		5.47	4.18	+30.9	22	B	L	line
Mason & Kendall (1979)		62.0	52.0	+19.0	20	B	S	slash
Negin (1982)		9.3	8.1	+16.1	120	B	S	1
North& Jenkins (1951)		494.0	448.0	+10.9	48	W	L&S	5
O'Shea & Sindelar (1983)		68.1	63.4	+ 7.4	85	B	S	slash
Stevens (1981)		65.0	54.0	+11.0				

Non-Significant Studies

		Phrase	Non-Phrase	Λ%	Ss	Design	Ph. Size	Sp. Size
Coleman & Kim (1961)		14.0	13.2	+ 6.0	64	W	S	1
Hartley & Burnhill (1971)		4.61	4.37	+ 5.5	49	W	L	lines

Formatting Summary (experiments listed above)

Phrase, Non-Phrase = self-explanatory
Λ% = percent difference between conditions
Design = B: between subjects, W: within subjects
Ph. Size = phrase size, L: only major boundaries; S: only minor boundaries
Sp. Size = spacing size: number of regular spaces inserted

The following studies report a significant improvement as a function of phrase-based spacing of printed or displayed text.
Bever et al. (in preparation). Forty community college subjects responded to two subtests of the Cook-Chapman test; the first subtest was normally formatted, while the second was formatted normally or phrased. The score represents the percent improvement on the second test as a function of format: a. is the score for all subjects, b. is the score for poor readers. Phrased texts were assigned and spaces added as in experiment 1 of Jandreau et al.
Frase and Schwartz, (1979). College graduates read Bell System technical documents, then made true/false decisions about new sentences, with access to original text. Numbers are average time taken to verify whether a test sentence is true or false. Phrased texts presented a proposition on each line, non-phrased texts were in standard format. Experiments 1 (8 subjects) and 2 (16 subjects) had materials which indented each phrase as well as placing it on a separate line. Experi-

ment 3 (their number 5, 16 subjects) had a left-justified format.
Hartley, (1980). Experiment 1—Modified replication of Frase and Schwartz (1979). Subjects answered all questions at once. Numbers are time in minutes. 18 subjects in each condition. Materials were also indented. Experiment 2—Materials not indented, 12 subjects in each condition. N.B. The overall ANOVA did not reveal a significant effect of format, but t-test comparisons were significant.

Jandreau et al., (1986). Eighty subjects divided into 4 groups (experiments 4 and 5) read one version of Cook-Chapman, find-the-odd-word materials, in one of four formats. Numbers refer to the mean number of words read in 2 1/2 minutes while performing the task. The phrased materials in experiment 1 had extra spacing only at major phrase boundaries (space size was a positive function of the word length of the preceding phrase); in experiment two proportional extra spacing was added following minor and major phrase boundaries. Phrase structure was assigned by the computer program, cyclephrase, with a full space variation.

Mason and Kendall, (1979). Two groups of 11 fourth graders, classified as poor readers, read three 69-word paragraphs, either all in the phrased or normal format. Large phrases were presented on separate lines; the control format was standard. A is the percentage of comprehension questions answered correctly; B. is the time in seconds to read each passage.

North and Jenkins, (1951). Two groups of 60 college freshman read either one phrased or normal *Readers Digest* articles, each in two minutes. a. is the number of words read; b. is the number of correct content questions; c. is percent correct on questions on material actually read. Phrased texts added an extra space between major phrases (='thought units' but not necessarily propositions).

Anglin and Miller, (1968). Twelve subjects read two essays, one phrased and one non-phrased. Phrases were presented one at a time; phrases were major, 4-7 words, usually proposition-bearing units. Numbers are number of words recalled a. after one and b. three trials (read from their figure 1).

Brozo, Schmeler and Spires, (1983). Fifty-eight college students, good readers (>75th percentile) read either phrased or non-phrased subtest from the Minnesota reading assessment test. Numbers are the mean performance on comprehenssion questions. Phrases were assigned and marked as in Stevens (1981).

Cromer, (1970). Sixty-four junior college students read both phrased and normal texts grouped in 4 sets of 5 stories from a standard test for college-high school students. Number reports percentage of the scores above or below the overall subject mean number of questions on comprehension test (Cromer reported his results in terms of normalized z-scores by subject, which we converted back to percentages of distribution above and below the mean—assuming normal distribution). Numbers are a. for all readers; b. for good readers (164 on the ETS cooperative English test); c. for poor readers. Phrased text placed three extra spaces between propositions, (='thought units').

Gerrell and Mason, (1983). Thirty 5th grade students read both standard and phrased reader texts presented on a computer screen and answered content questions. Numbers refer to percentage correct on those questions. Phrased texts had extra 'spaces' placed between 'intuitively arrived at phrases.'

Graf and Torrey, (1966). Thirty-two undergraduates read both phrased and antiphrased test essays, presented one text line at a time, moving down the page. Reading speed was adjusted to be slightly too fast for each individual subject. Values report mean correct on a post text comprehension test. Phrased texts presented major phrases on each line, (not necessarily propositions) antiphrased texts presented sequences bounded by minor boundaries: the two treatments were equated for even number of letters per line, about 3-5 words per line.

Negin, (1987). Two groups of 10 hearing-impaired subjects read either phrased or non-phrased texts. Numbers are comprehension test scores. Phrases were assigned as in Klare et al, and marked with blue slashes.

O'Shea and Sindelar, (1983). Forty-eight 1st and 3rd graders read two 200-word stories, one normal and one phrased, in counterbalanced

order, in a maze reading task. At selected points in each paragraph, subjects had to choose which word is appropriate, given three choices. Numbers are the average scores on the test. Phrased text followed Klare et al, and used 5 spaces between phrases.

Stevens, (1981). Eighty-five high school students read one phrased and one non-phrased form of the Gates-Macginitie test (level f). Numbers are scores on following comprehension tests. Phrased texts had slashes at each phrase point. Phrases were intuitively assigned small units.

The following studies tested some kinds of phrase-based spacing but did not report significant results.

Coleman and Kim, (1961). Sixty-four Johns Hopkins undergraduates read both phrased and normal 1500-word complex texts and answered content questions. Numbers are: a. average number correct on those questions; b. reading speed in words per minute. Phrased texts had one extra space placed between short phrases.

Klare et al., (1957). One hundred and seven airmen read normal and another 107 read phrased versions of a 1200-word text on engine repair, followed by comprehension questions. Numbers are mean time to read the text (they do not report comprehension performance). Phrased texts were marked by at least four extra spaces between short phrases.

Carver, (1970). Eighteen college students read short passages from a reading test, both phrased and normal: a. is average number correct answers to a comprehension test; b. is average reading time. Phrased texts had at least four extra spaces placed between short phrases, following Klare et al.

Keenan, (1984). Four groups of 6 clerical staff (Bell Labs) each read 4 short texts (120 words) in one of four formats: phrased-printed, normal-printed, phrased-screen, normal-screen. Each text was followed by comprehension measures. Numbers report reading rate in characters per second. Phrased text was presented as in Frase and Schwartz, 1/2 with short phrases on separate lines, 1/2 with propositions on separate lines.

Taylor, Wade and Yekovich, (1985). Two groups of 111 fifth grade students read 200-word passages. The numbers are the percentage of 'idea units' recalled: a. in free recall, and b. in both free and cued recall (from their 'no-practice' condition). Phrased texts had one 'idea unit' per line.

Hartley and Burnhill, (1971). Volunteers in a first year psychology course read two 2500-word scripts taken from Radio Three broadcasts, Each script had eight written comprehension questions. Numbers represent the average number of correct answers.

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