British Journal of Educational Psychology (2002), 72, 213–226
© 2002 The British Psychological Society
www.bps.org.uk

Reading at a distance: Implications for the design of text in children's big books

Laura E. Hughes and Arnold J. Wilkins*

Visual Perception Unit, Department of Psychology, University of Essex, UK

Background. Visual acuity, typically measured by the ability to name letters at a distance, is poorer when letters are small and closely spaced. It has been suggested that reading can be affected by letter size and spacing.

Aim. To determine the effect of text size and spacing on the ability to read at a distance, with a view to helping with the design of text in children's 'Big Books'.

Sample. The visual acuity of 200 children aged between 6 and 12 was measured. A subset of 66 children was given further reading tests.

Method. From a viewing distance of 3m children were required (1) to identify words and (2) to read passages of text rapidly. A repeated measures design was used to compare the effects of different size and spacing of text on performance of the two tasks.

Results. Performance improved when the spacing of words and size of letters was greater than is typical in 'Big Books'. For a given letter density, increasing the spacing improved performance more than increasing the letter size.

Conclusion. The text in children's books could be made easier to read by expanding the spacing between words and also by increasing the size of the print. The maximum viewing distance should be reduced from 15ft (4.6m) to 10ft (3.0m).

Reading is a highly visual task (Massaro & Cohen 1994) requiring rapid and accurate translation from orthography to phonology (Manis, Szeszulski, Holt, & Graves, 1990). If perceptual analysis is inadequate poor reading may result (e.g., Rumelhart, 1977; Stanovich, 1980). Clear and legible text is, therefore, vital for competent reading. Characteristics such as the font, the size of the type, and the amount of spacing are thought to influence legibility (e.g., Tinker, 1963; Walker, 1992; Watts & Nisbett, 1974; Wilkins, 1995). It is therefore important to establish the interaction between visual

*Requests for reprints should be addressed to Professor A.J. Wilkins, Visual Perception Unit, Psychology Department, University of Essex, Colchester, CO4 3SQ, UK.

function in children and the legibility of text they are reading.

One measure of visual function in widespread clinical use is the ability to see small letters at a distance. This ability is usually expressed as a fraction, e.g., 6/6 (or 20/20). The numerator refers to the distance at which the letter is viewed (typically 6m or 20ft). The denominator refers to the maximum distance at which the individual can successfully identify the letters. The fraction is sometimes reduced to decimal notation (6/6 = 1.0). An acuity of 6/6 (or 1.0) is 'normal', and an acuity of 6/9 (or 0.67), for example, indicates that the acuity is poor: the individual can only just see letters that a normal individual would be expected to read at 9m. The 6/6 (1.0) limit is measured using capital letters that subtend 5 minutes of arc at the eye and at 6m are therefore 9mm high.

In normal sighted children, the ability to see single isolated letters is greater than the ability to see groups of letters, e.g., the lines of letters on a conventional eye chart. The ability to see lines of letters is sometimes referred to as linear acuity. Single letter acuity appears to develop much earlier than linear acuity, approaching adult level (nominally 6/6 or 1.0) at the age of 5 or 6 years (Kothe & Regan, 1990a; Fern & Manny 1986). Simmers (1997) tested the linear and single letter acuity of 93 children aged 5.4 (+/−3 months) using the Glasgow Acuity Cards. Single letter acuity ranged between 0.875 and 1.15, with a mean of 1.02 +/−0.08 (right eye) and 1.01 +/−0.06 (left eye). The mean thresholds for single letters were therefore close to the nominal normal value of 1.0. In contrast, linear acuity ranged between 0.7 and 1.05. The mean visual thresholds were 0.89 +/− 0.07 (right eye) and 0.90 +/− 0.08 (left eye).

The discrepancy between linear and single letter acuity is well documented: evidently visual acuity depends not only on the size of the letters but also on their separation. Flom (1991) attributed the effect of separation to *crowding*. Aspects of crowding include contour interaction, which involves spatial interference and lateral masking. The effects of surrounding contours are maximal up to approximately the width of one letter (Flom, Weymouth, & Kahneman, 1963). This contour interaction can be demonstrated with simple targets (such as Landolt C) and is independent of eye movement. In addition to contour interaction, Flom suggested that crowding may involve attentional factors for which eye movement control may be important, as when attention is divided between several letter targets. Attentional factors might be expected to show a greater effect of age than those of contour interaction, and play a disproportionately greater role in young children.

The spacing of letters does not only affect how easily they may be seen, it also affects their apparent size, perhaps for related reasons. Skottun and Freeman (1983) studied spacing between letters and apparent letter size in relation to acuity. Acuity levels for letters with five different spacings were measured. When letters were closely spaced, acuity was poorest, and this effect diminished as letter spacing increased, up to a separation of about 3 minarc after which acuity was relatively unaffected. This critical value of 3 minarc also occured when perceived letter size was tested. Widely spaced letters, of the same height, tended to appear larger than letters that were closely spaced. Participants' estimates of the size of letters that were closely spaced were fairly accurate but as letter separation increased so did perceived size. Increasing the *separation* of letters from 0.8 to 9 minarc resulted in a 20% increase in their perceived size, and this occurred for both smaller and larger letters. One suggested reason for this illusion is related to the lateral masking effect. Letters that are uncrowded appear clearer and thus may also appear to be larger.

The effects of crowding and contour interaction have been related to reading

(Hohmann & Haase, 1982). In reading books for lower grades there may be fewer crowding effects because of the larger print and more generous spacing. Books for older readers, however, have smaller letters that are sometimes almost adjoining. It may be expected, then, that some children have difficulty reading small closely spaced print, particularly when linear acuity is still developing. Kothe and Regan (1990b) also suggest that large crowding effects during early childhood could hinder the acquisition of reading skills, even in children with a good visual acuity. Conventional printed text is usually closely spaced, beyond the critical one-letter width at which crowding becomes appreciable. Of course, experienced readers are not normally required to recognise the component letters within words: they overcome the effects of crowding using their knowledge of words and word shape; however, younger readers rely on letter to sound mappings when learning new words (Frith, 1985). With young readers who lack such knowledge it may be particularly important to avoid crowding effects, and facilitate the recognition of words via letter-by-letter reading.

Print size also has a strong influence on reading fluency. Bailey, Clear, and Berman (1993) suggest reading speed is fastest at three times the level of visual acuity. Reading speed can increase to a maximum level over a critical range of print size (characters subtending 0.3deg to 2deg) beyond which speed varies little until letters become extremely large (Chung, Mansfield, & Legge, 1998). Reading rate is poor with very small letters below an acuity level of 6/6 (Legge, Pell, Rubin, & Schleske 1985). Erdman and Neal (1968) and Blommaert and Timmers (1987) both demonstrated that adults found it more difficult to recognise words and letters when the print size was reduced. Cornelissen, Bradley, Fowler, and Stein (1991) report an increase in visuo-perceptual problems in proportion to a decrease in spatial dimensions of text. More errors were made by the children tested as the print size was reduced, and children with visual deficits made significantly more errors on smaller than on larger sized text.

In addition to the above effects of text parameters on visibility and reading fluency, there are effects on visual stress (Wilkins, 1995). Text with small spacing can have aversive properties similar to certain patterns of stripes that cause visual illusions. Text with these properties can make reading visually stressful (Wilkins & Nimmo-Smith, 1987).

The text in children's reading books typically reduces in x-height and spacing as the reader's age increases. Thus the child has to contend with an increase in visuo-perceptual complexity as well as a more complex semantic and linguistic content. We have shown that the decrease in size and spacing of text with reading age is too great and that reading speed is compromised (Hughes & Wilkins, 2000).

In September 1998 the National Literacy Strategy (NLS) encouraged new ways to teach reading within the classroom with the introduction of Literacy Hour and 'Big Books'. Big Books are approximately A3 size and are intended to be read by groups at a distance. The maximum distance as suggested by the NLS was 15ft (4.57m).

A sample of text from different Big Books was measured and these measurements are listed in Table 1. These books are intended for shared reading by children aged six to eight.

The visual aspects of reading can be measured using the Rate of Reading Test © designed by Wilkins, Jeanes, Pumfrey, and Laskier (1996) which minimises the linguistic and semantic aspects of reading and maximises visual difficulties. It comprises 10 lines each of the same 15 common words in a different random order. The text appears as a paragraph and lacks any meaning. The Rate of Reading Test is designed to compare each participant's performance under different visual conditions: reading

Table 1. Measurements (in mm) of text examples taken from a selection of children's Big Books

Publishers	Book Titles	x-height	Stroke Width	Inter-letter spacing	Line Spacing
Collins	*Suddenly*	9.6	0.18	10.5	2.50
Collins Educational	*Time and Space*	5.1	0.01	4.8	1.27
Era	*One Wobbly Wheelbarrow*	6.6	0.11	5.9	2.20
Evans	*What Was It Like Before Electricity?*	6.9	0.12	6.5	2.05
Longman	*What Babies Used to Wear.*	8.8	0.23	8.9	2.70
Macdonald	*Grandma's Bill*	5.1	0.09	5.0	1.40
Mimosa	*A Week Away*	7.5	0.12	7.5	1.72
Nelson	*McBungles African Safari*	10.5	2.20	7.7	2.65
OUP	*Big Book of Poetry*	5.0	0.10	5.5	1.27
OUP	*Spiders are Amazing*	5.8	0.11	6.2	1.44
Picture Mammoth	*The 3 Little Wolves and Big Bad Pig*	5.3	0.08	5.1	1.47
Scholastic	*Whistling Thorn*	7.2	0.10	5.7	2.50
Shortland	*Life and Living*	7.2	0.26	6.9	2.10
Walker Books	*Think of an Eel*	4.8	0.08	4.1	1.78

speeds vary considerably from person to person but are highly reliable at re-test.

The present study examines how different letter sizes and the spacing of words and lines affect children's reading. Children were asked to identify at a distance of three metres single isolated letters (single letter acuity), a row of letters as in a conventional eye chart (linear acuity), and a line of crowded words (word acuity). They were also asked to read aloud passages of text composed of randomly ordered common words (Rate of Reading Test). The reading speed and errors were measured. The acuity tests were expected to demonstrate the effect of crowding and to be related to measurements of reading speed. It was also expected that children's word acuity and reading fluency would be improved by larger letter sizes and expanded spacing. The effects of letter size and spacing in these various tasks was compared, and related to the design of text in Big Books.

Method

Design

A repeated measures design was used in each of two groups. In Group 1 each child was given a linear and single letter acuity test and a standard Rate of Reading Test. In Group 2 each child was given a short linear and single letter acuity test, a Word Acuity Task and four versions of the Rate of Reading Test. The timed period for the Rate of Reading Test was reduced from one minute to 30 seconds in order to minimise tiredness anticipated in the younger children. The order of presentation of the reading tests was randomised. Order of presentation of the Word Acuity Task depended on the child's linear acuity.

Sample

Group 1 included 134 children aged between 8 and 11 from a mainstream primary school in Norwich. Group 2 included 66 children aged between 6 and 11 from a mainstream primary school in Colchester. Fifteen children were selected from each of the first two year groups and 12 children were selected from each of years 4, 5 and 6. All were selected alphabetically by surname (the first available from each class register).

Materials

Linear acuity was tested with the LogMAR Crowded Acuity Test and single letter acuity was tested with individual letters taken from the Crowded Acuity Test. A Word Acuity Task and four versions of the Rate of Reading Tests were created.

The Word Acuity Task was intended to measure children's ability to see and read words at a distance, and be a word acuity rather than a reading task. The task comprised two sets (set A or set B) of four books, each with an acuity level equivalent to 6/6, 6/5, 6/3.75 or 6/3 (1.0, 1.2, 1.6, 2.0). Five pages in each book contained three lines of three words, but the children were asked to read only the centre line. In each book the word and line spacing were manipulated to provide expanded, default spaced or crowded text. The spacing measurements are provided in Table 2. Figure 1 provides an example of three levels of text the children were asked to read.

Table 2. Approximate size and spacing of letters used in the Word Acuity Task (mm)

Test Booklet x-height		Very Crowded	Crowded	Default	Expanded	Very Expanded
2.2	Letter spacing	1.97	2.00	2.07	2.12	2.18
	Line Spacing	4.00	4.40	5.00	5.15	5.40
2.9	Letter spacing	2.50	2.59	2.65	2.71	2.80
	Line Spacing	5.70	6.00	6.35	6.75	7.10
3.5	Letter spacing	3.00	3.16	3.25	3.33	3.45
	Line Spacing	6.40	7.30	7.80	8.50	9.10
4.5	Letter spacing	3.80	3.95	4.07	4.19	4.33
	Line Spacing	8.70	9.50	10.02	10.9	11.6

Two of the four versions of the Rate of Reading Test were based on Oxford University Press' Big Books using a similar font (Geneva) and font size (x-heights of either 5 or 5.8 mm) and similar line, word and letter spacing. The other two tests used the same font and x-heights but the spacing was increased (word spacing increased by 5% and line spacing increased by 10%). These tests are referred to respectively as 5mm default, 5.8mm default 5mm expanded, and 5.8mm expanded.

Procedure

The acuity of each child was first tested with the single letter acuity test and then linear acuity was tested with the LogMAR Crowded Acuity Test. Only one eye was tested, alternating left and right eye from one child to the next unless the child reported that one eye had poor vision. Using both eyes the child was asked to read the middle line of words in the Word Acuity Task. Either set A or set B books were used (alternately with

(a) bury cult cord take
you see the
shoe wolf iron free

(b) cult luck take navy
cat you for
play bury cord iron

(c) sure envy navy iron
and see not
mist soul luck shoe

Figure 1. An example of crowded (a), default (b) and expanded (c) text from the Word Acuity Task with an x-height of 2.2mm

each child), starting with the test equivalent in x-height to the child's linear acuity and then the next acuity level down (smaller letters). The child was then given the example Rate of Reading Test to read. The child viewed all four Rate of Reading Tests at a distance of 15ft (4.57m), the maximum recommended for the Big Books. The child was asked if any were easier or clearer to see, and which were harder or unclear. The child was then asked to read each test at three metres. The number of words read and number of errors were recorded.

Results

Acuity measures

The acuity levels for all the children are displayed in Figure 2. The mean linear and single letter acuity levels for children aged between 6 and 12 were 1.077 and 1.15 respectively.

Both single letter acuity and linear acuity (Crowded Acuity Test) were related to reading speed (Group 1: single letter acuity $r = .2$, $p < .05$; linear acuity $r = .23$, $p < .1$); Group 2: single letter acuity $r = .4$, $p < .01$; linear acuity $r = .4$, $p < .01$). Thus we can expect children who have lower acuity levels to be less fluent when reading at a distance. Linear and letter acuity were also highly correlated with the Word Acuity Task ($r = .6$ $p < .01$) showing it to be a valid test of acuity.

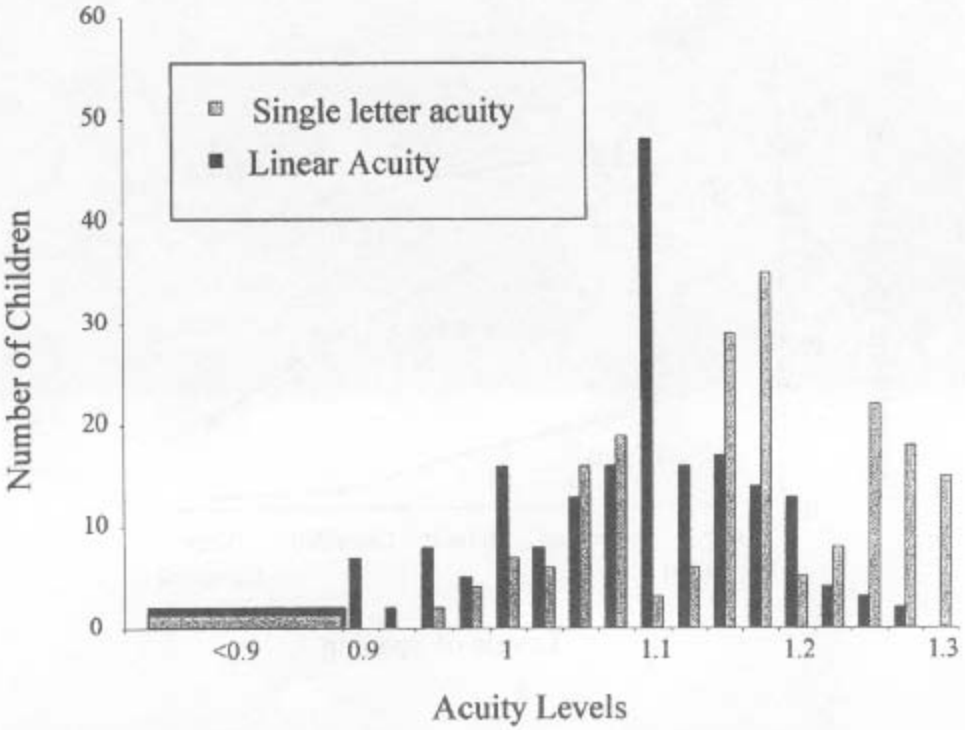

Figure 2. The single letter and linear acuity levels for 200 children aged between 6 and 12 years

Effects of space on reading

Word Acuity Task

The percentage of children who could read words at different levels of spacing and letter size is shown in Figure 3. The key shows the x-height of the text in millimetres, and also the word acuity level equivalent to linear acuity on the Crowded Acuity Test. All the children could read the larger text with default spacing or greater; the effects of spacing appeared with smaller sized text. As is clearly evident from the figure, fewer children could see the text as the size and spacing decreased.

When threshold levels of acuity were analysed, using a repeated measures analysis of variance, there were significant differences between the four sizes of text ($F(3,260) = 111.2$, $p < .0001$). There were also significant differences in acuity over the five levels of spacing. Acuity for words with default spacing was poor compared with acuity for words having either *very expanded* and *expanded* spacing (*very expanded*: $t(65) = 7.13$, $p < .001$; *expanded*: $t(65) = 4.9$, $p < .001$).

Word acuity was increased by 0.1 in 44% of children when the spacing was increased from *default* to *very expanded*. When the spacing was increased from *very crowded* to *very expanded* 92% of children had an increase of acuity between 0.1 and 0.3.

Figure 4 illustrates the change in word acuity with the size and the spacing of the text, expressed as letter density. Letter density was calculated as the average area of the page used per letter, including the surrounding spaces (i.e., including interletter and line spacing).

It appears that word visibility (as suggested by the number of children able to

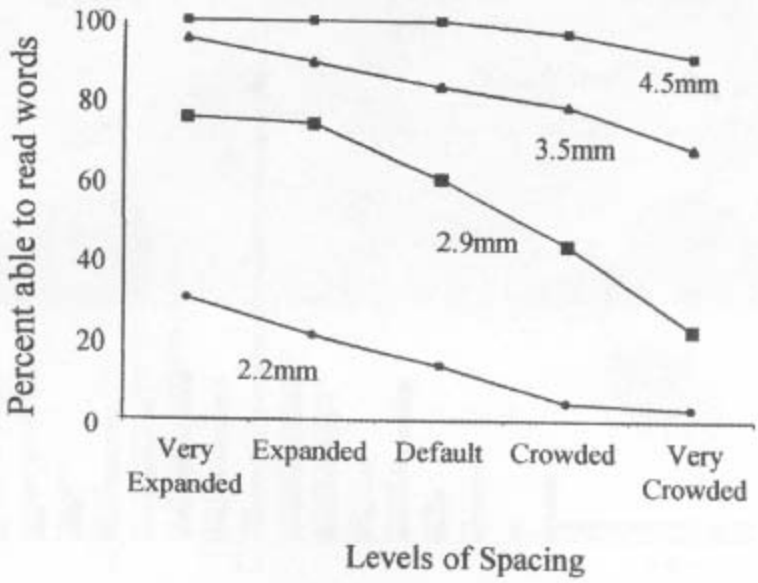

Figure 3. The percentage of children who could read words (at 3 metres) in the Word Acuity Task with different levels of spacing and different text sizes. The key shows the x-height of the text in mm

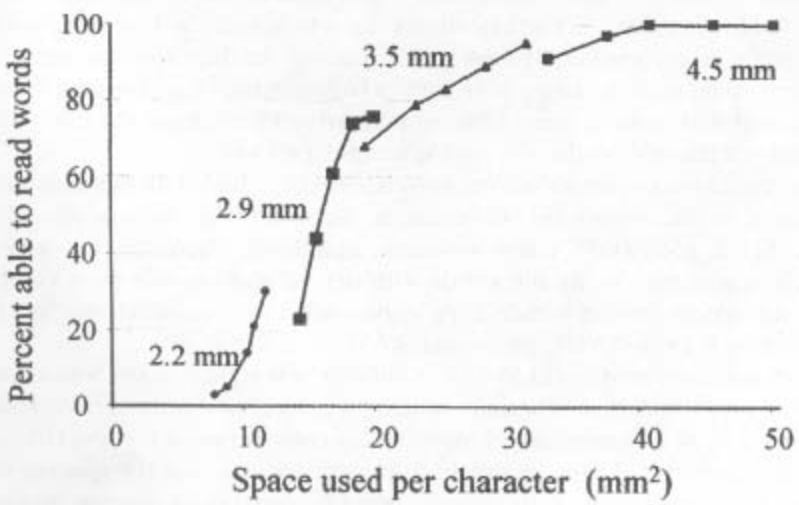

Figure 4. The effect of space used per character on the ability to name words in the Word Acuity Task

identify the words) is generally increased by a decrease in letter density, as might be expected. Note, however, that for a given letter density reading is not improved by a larger x-height but by the amount of space surrounding the letter. In other words, for a given letter density, it may be preferable to increase the spacing rather than the letter size to achieve an improvement in visibility.

Rate of Reading Tests

The four Rate of Reading Tests demonstrate that the size and spacing of text affect children's reading speed. Figure 5 shows the mean reading speed of each year group on the four Rate of Reading Tests.

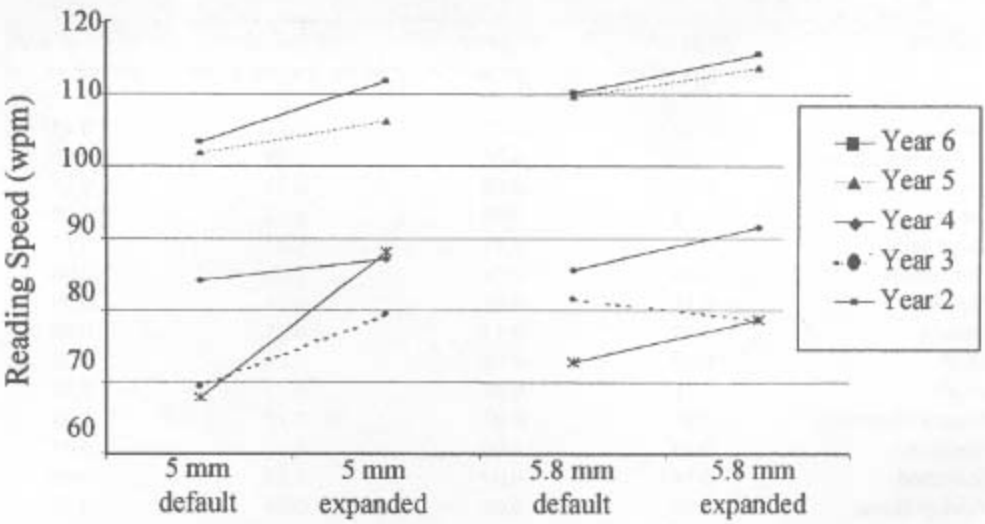

Figure 5. The mean reading speeds of children in each year group over the four Rate of Reading Tests

Significant differences were observed between all four Rate of Reading Tests ($F(3,195) = 14.947$, $p < .001$). The larger spaced text (5.8mm expanded) was read fastest and the smaller default spaced text (5mm default) read slowest. Interestingly, the 5mm expanded text was read more fluently than the larger 5.8mm text with default spacing by three of the age groups, the difference being largest with the younger age group, year 2. Although this difference is only marginally significant ($t = 1.4$, $p < .1$) it suggests that space can be more important than size.

Children's opinions

The children's views of the text reflected their rate of reading scores. The children preferred the larger x-heights than the smaller, and the expanded text than the crowded text. When they were asked which texts were more difficult to see 75% of children said the 5mm texts. When the children were asked which texts were easier to see, their responses were consistent. The children were also aware of the effects of spacing the texts: 52% of the children named the expanded 5.8mm text as easiest.

Measurements of Big Books

The tables below provide measurements of the selection of books (Table 3) which are comparable with those from the Word Acuity Task (Table 4). From these it is possible to deduce the level of acuity needed to read text at different distances. These measurements suggest that at 3m most of the books have expanded spacing and words large enough for the acuity levels of most children. At 15ft all but three books have acuity levels equivalent to 1.2 or 1.3.

Table 3. The angle of subtense (in degrees) for the x-height and letter spacing at 3 metres and 15 feet in the selection of big books

Publishers	Angle of x-height at 3m	Angle of x-height at 15ft	Angle of letter spacing at 3m	Angle of letter spacing at 15ft
Collins	0.18	0.12	0.20	0.13
Collins Educational	0.10	0.06	0.09	0.06
Era	0.13	0.08	0.11	0.07
Evans	0.13	0.09	0.12	0.08
Longman	0.17	0.11	0.17	0.11
Macdonald	0.10	0.06	0.10	0.06
Mimosa	0.14	0.09	0.14	0.09
Nelson	0.20	0.13	0.15	0.09
OUP	0.10	0.06	0.11	0.07
OUP	0.11	0.08	0.12	0.07
Picture Mammoth	0.10	0.07	0.10	0.06
Scholastic	0.14	0.09	0.11	0.07
Shortland	0.14	0.09	0.13	0.08
Walker Books	0.09	0.06	0.08	0.05

Discussion

The single letter acuity levels were higher than the linear acuity levels, confirming that children are susceptible to crowding in letter naming. Crowding effects, consistent

Table 4. The angle of subtense (in degrees) for the x-height (in mm) and letter spacing in the Crowded Acuity Task and the Word Acuity Task

CAT Levels	Word Acuity Task x-height	Angle of x-height at 3m	Angle of CAT letter spacing at 3m	Angle of Word Acuity Task letter spacing at 3m
0.9		0.11	0.16	
1.0	4.6	0.09	0.13	.073–.083
1.1	3.5	0.07	0.10	.057–.066
1.2	2.9	0.06	0.08	.048–.053
1.3	2.2	0.04	0.06	.038–.042

with many previous data, were also demonstrated when reading words, as shown by the Word Acuity Task, and when reading strings of words, as shown by the Rate of Reading Tests. The children's reading in both the Word Acuity Task and Rate of Reading Test improved when the spaces within the text were expanded. This was more notable for smaller than for larger text.

The size of the text also influenced reading fluency. There was a tendency for children to read larger text more fluently than smaller text, as might be expected, but smaller text with expanded spacing was read with a speed equivalent to or better than larger crowded text. This suggests spacing may be more important than size. The children themselves noticed a difference in clarity between large and small text and expanded and crowded text. The larger texts were reported as being easier to see than the smaller texts and the spaced text as clearer than the crowded text.

These data support the results of previous research and have important implications for the design of text in children's books. In accordance with other studies (e.g., Flom, 1991; Simmers, 1997), a difference between linear and single letter acuity is observed, which may be attributable to crowding, suggesting that the children are susceptible to the effects of spacing. This susceptibility is reflected in their reading; the children had greater word acuity for spaced than crowded words, and they were more fluent with the expanded than the default text in the Rate of Reading Test. Note that the default text had typography similar to that which the child would normally encounter.

The discrepancy between the children's acuity with the closely spaced and expanded text in the Word Acuity Task and in the Rate of Reading Tests may also be attributable to contour interaction and crowding. Flom (1991) suggests the effects of contour interaction are maximal up to one letter width, which is the level of spacing between words in the crowded text in both the word acuity and the default Rate of Reading Test.

Perceived size may also be related to crowding. Letters which are further apart appear larger and clearer (Skottun & Freeman, 1983) and the children noted this themselves in the Rate of Reading Tests; the expanded texts were named as clearer than the crowded texts of the equivalent x-height.

An additional factor involved may be visual stress. Visual stress when reading may occur because text has properties similar to particular patterns of stripes which cause illusions (Wilkins & Nimmo-Smith, 1987). Patterns of this kind are most aversive when they have a spatial frequency of about 1–3 cycles per degree. The line spacing of the text in the Big Books is small. At three metres all the books sampled are within the stressful range. The 5mm and 5.8mm crowded Rate of Reading Tests have spatial frequencies of 4.12 and 3.64 cycle.deg^{-1} respectively. These frequencies are reduced when the spacing is increased, although not below a frequency of 1 cycle deg^{-1}. The text may therefore have aspects of visual stress which increases the complexity of visual processing.

The importance of inter- and intra-linear spacing is highlighted in the Word Acuity Task. This measure demonstrated that children's word acuity increases significantly in proportion to an increase in the amount of space allowed per character. Word acuity increases by 0.1 in 44% of children when spacing is increased from *default* to *very expanded*.

The size of the print also influenced the children's reading, although there was an important interaction with spacing. In the word acuity test children's acuity was better for smaller text with expanded spacing than text which was larger but had crowded spacing. Thus text which is smaller in x-height but allows more space per character had greater clarity than text which is larger in x-height but allows the same space per character. A similar effect also occurred with the Rate of Reading Tests; many of the children read the smaller spaced text faster than the larger more crowded text. This suggests that space can be more important than size of text, and improving clarity does not necessarily mean increasing the costs of printing. The implications of the crowding effects suggest that reading can be improved by by expanding the spacing horizontally and vertically, minimising contour interaction and crowding effects. The expansion of spacing would also be predicted to reduce visual stress, according to the parameters identified by Wilkins (1995).

Implications for the design of Big Books

The measurements taken from the Big Books can be compared to previous research findings and also to the size and spacings in the acuity test. Previous studies suggest that the critical print size for optimal reading subtends between 0.3 and 2 degrees (Legge *et al.*, 1985; Chung *et al.*, 1998). In all the books sampled, none of the text was within this range until the reading distance was reduced to less than one metre. The data from the acuity measures can be extrapolated to suggest the acuity levels needed to read Big Books at various distances. From the sampled Big Books at a reading distance of three metres the size and spacing of the text is adequate for most children's acuity levels; however, at greater distances reading will be much poorer. At 15ft (4.572m) only three books have text with an x-height equivalent to a word acuity of 1.1 at most. Seventy per cent of children have a word acuity greater than 1.1 for crowded text and thus may be able to read these books. Six books have text equivalent to a 1.2 acuity level which less than 23% of children are likely to be able to cope with. Five books have an acuity level of 1.3, which is suitable for less than 3% of children. The Rate of Reading Tests provide additional support for the above assertions. At a reading distance of 3 metres the default text was adequate for most children's level of acuity and yet reading fluency still improved when the spacing was expanded.

Moreover, both the word acuity test and the Rate of Reading Test show that size is not the single most important factor in reading fluency. The children found text that is well spaced but smaller in x-height easier to read than larger text with less spacing.

Conclusion

The measures of children's acuity and reading fluency demonstrate that small text size and spacing can adversely influence reading. These measures can also be used to determine the ability of children to read the Big Books at different distances. At three metres most children have adequate acuity to see the text, although their reading fluency may be adversely affected. At greater distances many children are trying to read at or below their acuity limit. At a distance of three metres reading could still be improved by expanding the spacing and increasing the font size of the text. However, text size does not appear to be the most single important factor in word acuity and reading fluency; good spacing is vital to reduce crowding effects and visual stress. We

conclude that children's reading would benefit by increasing the font size of the text and by expanding the spacing horizontally and vertically. The recommended maximum viewing distance should be reduced from 15ft to 10ft (3m).

Acknowledgements

The authors thank the staff and children of St Johns Green School, Colchester, and the Avenue Middle School, Norwich, for their kind assistance and co-operation.

References

Bailey, I., Clear, R., & Berman, S. (1993). Size as a determinant of reading speed. *Journal of the Illuminating Engineering Society, 22*(2), 102–117.

Blommaert, F.J., & Timmers, H. (1987). Letter recognition at low contrast levels: Effect of letter size. *Perception, 16*, 421–432.

Chung, S., Mansfield, J.S., & Legge, G.E. (1998). Psychophysics of reading. XVIII. The effect of print size on reading speed in normal and peripheral vision. *Vision Research, 38*, 2949–2962.

Cornelissen, P., Bradley, L., Fowler, S., & Stein, J. (1991). What children see affects how they read. *Developmental Medicine and Child Neurology, 33*(9), 755–762.

Erdman, R.L., & Neal, A.S. (1968). Word legibility as a function of letter legibility, with word size, word familiarity and resolution as parameters. *Journal of Applied Psychology, 52*, 403–409.

Fern, K.D., & Manny, R.E. (1986). Visual acuity of preschool children: A review. *American Journal of Optometry & Physiological Optics, 63*, 319–345.

Flom, M.C. (1991). Contour interaction and crowding. *Problems in Optometry, 3*(2), 237–257.

Flom, M.C., Weymouth, F.W., & Kahneman, D. (1963). Visual resolution and contour interaction. *Journal of Optical Society of America, 53*, 1026–1032.

Frith U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, M. Coltheart, & J. Marshall (Eds.), *Surface dyslexia*. Hove, Sussex: Erlbaum.

Hohmann, A., & Haase, W. (1982). Development of visual line acuity in humans. *Ophthalmic Research. 14*, 107–112.

Hughes, L.E., & Wilkins, A.J. (2000). Typography in children's reading schemes may be suboptimal: Evidence from measures of reading rate. *Journal of Research in Reading, 23*(3), 314-324.

Kothe, A.C., & Regan, D. (1990a). The component of gaze selection/control in the development of visual acuity in children. *Optometry and Vision Science, 67*(10), 770–777.

Kothe, A.C., & Regan, D. (1990b). Crowding depends on contrast. *Optometry and Vision Science, 67*(4), 283–286.

Legge, G.E., Pelli, D.G., Rubin, G.S., & Schleske, M.M. (1985). Psychophysics of reading. I. Normal vision. *Vision Research, 25*(2), 239–252.

Manis, F.R., Szeszulski, P.A., Holt, L.K., & Graves, K. (1990). Group differences in phonological decoding. In T.H. Carr & B.A. Levy (Eds.), *Reading and its development: Component skills approaches*. New York: Academic Press.

Massaro, D., & Cohen, M. (1994). Visual, orthographic, phonological and lexical influences in reading. *Journal of Experimental Psychology: Human Perception and Performance, 20*, 1107–1129.

Rumelhart, D.E. (1977). Toward an interactive model of reading. In S. Dornic & P. Rabbitt (Eds.), *Attention and performance VI* (pp. 573–603). Hillsdale, NJ: Erlbaum.

Simmers, A.J. (1997). *Clinical evaluation of visual dysfunction in human amblyopia and the effect of occlusion therapy*. Doctoral dissertation, Glasgow Caledonian University, Scotland.

Skottun, B.C., & Freeman, R.D. (1983). Perceived size of letters depends on inter-letter spacing: A new visual illusion. *Vision Research, 23*, 111–112.

Stanovich, K.E. (1980). Toward an interactive-compensatory model of individual differences in the development of reading fluency. *Reading Research Quarterly, 16*, 32–71.

Tinker, M.A. (1963). *Legibility of print*. Ames, IA: Iowa State University Press.

Walker, S. (1992). *How it looks: A teacher's guide to typography in children's reading books*. Reading and Language Information Centre, University of Reading.

Watts, L., & Nisbett, J. (1974). *Legibility in children's books: A review of research*. Windsor: NFER.

Wilkins, A.J. (1995). *Visual stress*. Oxford: Oxford University Press.

Wilkins, A.J., & Nimmo-Smith, M.I. (1987). The clarity and comfort of printed text. *Ergonomics, 30*(12), 1705–1720.

Wilkins, A.J., Jeanes, R.J., Pumfrey, P.D., & Laskier, M. (1996). Rate of Reading Test: Its reliability, and its validity in the assessment of the effects of coloured overlays. *Ophthalmic and Physiological Optics, 16*(6), 491–497.

Received 20 September 1999; revised version received 9 December 2000