

## **Lateral interference, spacing, and word legibility**

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### Abstract

Visual processing of individual characters within a word can interfere with one another thereby decreasing word legibility. This largely results from the lateral interference occurring in the retina and the primary visual cortex, with the distance over which it operates largely fixed in size. Analysis of previous data demonstrates that the default spacing for 10 and 12 pt font is just large enough to avoid significant lateral interference effects. These results suggest that empirical design skirts the limit of lateral interference and that lateral interference is to be avoided for good design.

This proposal suggests 2 areas of investigation related to the effects of lateral interference on font design.

The first relates to character spacing. Currently, common practice is that the same proportional spacing is applied to the range of font sizes; as a result the spacing of smaller fonts causes lateral interference effects and compromises word legibility. This suggests that proportional spacing across font sizes may not be the best strategy; word legibility for smaller fonts may be enhanced with greater spacing, and word legibility for larger fonts may be retained with decreased character spacing. We propose to test the effects of character spacing on word legibility and response time measures for a range of font sizes to include small and large fonts. This will test the hypothesis stated above and will provide data that can be used in design.

The second area of investigation relates to the specific lateral interference effects between adjoining letters. Different characters have different lateral contours. It is possible that the strength of lateral interference may be affected by the shapes of adjoining characters and by rendering technique. We propose to categorize character contours and determine the effect of type of letter contour and font rendering on character spacing. The expected findings will help improve character spacing in current and future font design.

### Background

Current default character spacing negatively affects word legibility. This has been shown for both size threshold determination of legibility and also for supra-threshold response time (RT) measurements.

Figure 1 shows word legibility data as a function of character spacing. These data were determined with the size-threshold method whereby the characters and words are effectively reduced in angular size to determine recognition threshold; a smaller size at threshold indicates better relative legibility. At default spacing, word legibility is clearly less than for an

individual letter; we have called this the “letter superiority effect.” This effect is almost certainly due to lateral interference (aka “contour interaction” and the “crowding phenomenon”), which is explained by the lateral inhibition known to exist in retina and primary visual cortex.

With increased character spacing, the word legibility likewise increases and reaches asymptote at approximately the same legibility as individual characters. The improvement in word legibility with increased spacing is likely due to reduced effect of lateral interference.

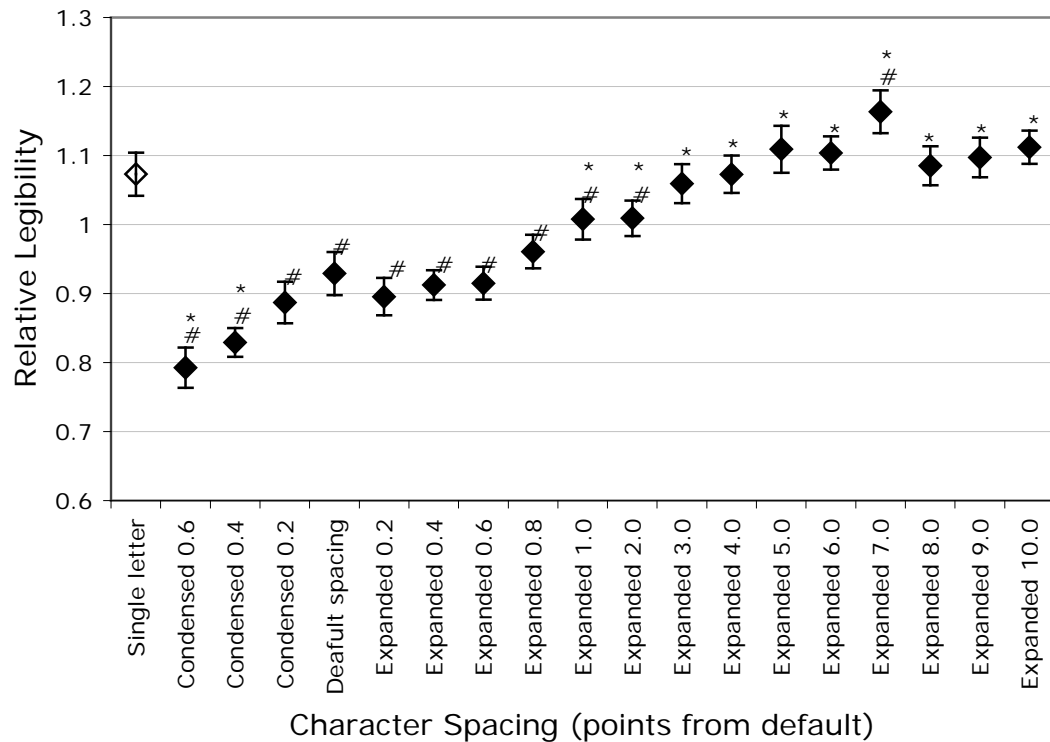
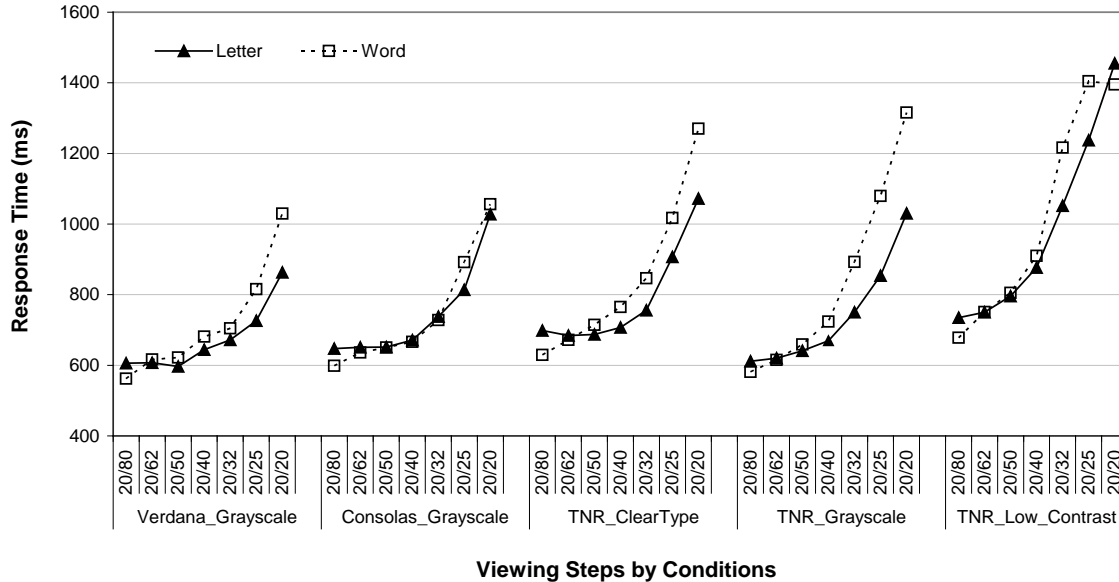


Figure 1: Relative legibility of individual letters and words with various spacing levels in the letter/word legibility task. Error bars are the standard error of measure. The “#” signs indicate a significant difference ( $p < 0.05$ ) from the single letter legibility; the “\*” signs indicate a significant difference ( $p < 0.05$ ) from the legibility for default character spacing.

The data in Figure 2 are response times for letters and words that are shown at various supra-threshold sizes – designated by the acuity size of the characters. According to the usual method of font scaling, character spacing within words was proportional to size – i.e. word shape integrity was maintained for different character sizes.

The letter superiority effect is demonstrated for smaller sized characters; i.e. the response time for smaller sized letters (20/20 to ~20/50) was faster than for words of the same size. However, for larger sizes the response times are similar for letters and words. These results show that the letter superiority

effect demonstrated at size threshold also exists for supra-threshold sized text, but that the magnitude of the effect decreases and asymptotes with larger character sizes.



**FIGURE 2.**

Average response time (RT) for orally reporting the identity of individual letters and words for the 5 font conditions. RTs are shown for several supra-threshold sizes (20/80 is largest). For a typical computer display viewing distance of 50 cm, 6, 8, 10, and 12 pt lower case Verdana font have acuity sizes of 20/41, 20/48, 20/54, and 20/66 respectively.

These findings provide further insight into the effect of lateral interference on character and word recognition. At larger sizes, when letter recognition is unburdened from the lateral interference of neighboring letters, words and letters have the same response times. At smaller sizes, where the characters are closer together and lateral interference is significant, the letters within a word interfere with one another, thereby rendering the word less legible than individual letters. Since lateral interference operates over a relatively fixed retinal distance, smaller spacing between characters causes a larger lateral interference effect on word recognition.

#### Implications for font spacing: Spacing and font size

The most commonly used font sizes for reading are between 10 and 12 pt – they have largely been empirically determined. For a typical computer screen viewing distance of 50 cm these lower case characters have acuity sizes of 20/54, and 20/66 respectively. As seen in Figure 2, these commonly used font sizes have greater acuity values for which the word response times are close to the asymptotic value; i.e. apparently just large enough to disengage the effects of lateral interference. However, 6 and 8 pt fonts (20/41 and 20/48) are more within the sloped portion of the curves for which

the response time is greater and for which there is a difference between letter and word response; i.e. lateral interference has a significant effect.

In typical text presentation, character spacing within words scales directly with character size. Such proportional scaling maintains the shape integrity of the word across all sizes, but perhaps is not the best strategy for optimizing reading performance. For standard 10 and 12 pt font, default proportional character spacing appears to be just large enough to optimize RT, whereas default proportional spacing for smaller font sizes does not. The effects of spacing on RT appear driven by lateral interference, the effect of which decreases with distance between contours. The default proportional spacing for 10 and 12 pt font avoids the effects of lateral interference, but not for smaller fonts. This suggests the likelihood that RT to words for smaller font sizes can be improved with greater spacing, and also that RT to words for larger font sizes would not be compromised with less spacing.

#### Implications for font spacing: Character-specific spacing

Different font designs entail different contours for individual letters. Lateral interference between characters therefore is likely determined by not only the actual spacing between the edge of adjoining characters but also the interaction between their contours. Figure 2 demonstrates that in some fonts, such as the mono-spacing Consolas, less lateral interference might result than others, such as the heavily shrifted TNR. Furthermore, it is likely that the contours of "oo" interfere with one another differently than "kf". The specific contours of each character and how they interact with characters with other types of contour are critical in determining optimal character spacing.

Furthermore, as has been adopted for font display, it is important to consider the additional effect of ClearType (CT) rendering on character and word legibility. Our findings suggest that lateral interference is exacerbated by the use of CT when default spacing and font size (11 pt) are used, and that smaller-font CT rendering impedes character and word legibility. It will be important to understand the effects of CT rendering on character spacing.

#### Proposed testing

We suggest 2 areas of testing concerning the effects of lateral interference.

- 1) Determine the minimal functional spacing: For a range of font sizes (6, 8, 10, 12, 14, and 16) and rendering methods (black&white, grayscale, and CT) at a typical working distance of 50 cm, we will test the effects of incremental spacing on word and letter response accuracy and reaction times, generating data similar to those in Figure 2. Spacing will be altered using techniques similar to those used to generate the stimuli for data in Figure 1. A minimum functional spacing for each font size and rendering method is determined as the smallest spacing that optimizes

the RT. We hypothesize that, relative to current default proportional spacing, the minimal functional optimal spacing will be larger for smaller font sizes and smaller for larger font sizes. These trends may be enhanced with CT.

Table 1: Lower case characters categorized according to left- and right-side contour shape. Numbers in the parenthesis indicates the additional frequency needed for displaying any of the characters in the cell to balance the frequency of all possible contour combinations. The total frequencies of contour types are 30 for straight, 31 for curved, 30 for slanted, and 31 for complex.

		Right side			
		Straight	Curved	Slanted	Complex
Left side	Straight	h i l m n u (0)	B p (+3)		k r (+3)
	Curved	d g q (+2)	O (+6)		c e (+3)
	Slanted			V w y (+15)	
	Complex	a j (+3)			f s t x z (+3)

2) Individual inter-letter lateral interference: We also hypothesize that specific contours can interact to affect the strength of lateral interference. To test this, the left and right edges of individual characters are assigned to four categories: straight (ST), curved (CV), slanted (SL), complex (CX), as shown in Table 1. Subjects will be asked to identify two horizontally adjoined letters, with all 676 combinations of letters tested in a random order. Additional redundant pairings will be added to balance the frequency of all 9 types of possible contour combination. The default spacing and 12 pt font size will be used to generate all characters with three rendering methods (black&white, grayscale, and CT). Letter identification accuracy and reaction time will be measured to determine the the level of lateral interference for each contour pairings and each combination of contour types. We hypothesize that higher contour interference will be observed for some specific pairing of contour types than others, and CT might have a higher degree of contour interference.

The results of these areas of research can lead to enhanced legibility from better character spacing across font sizes and between individual letters.