

Using the "Blur Tolerance" Technique to Predict and Optimize the Legibility Distance of Symbol Highway Signs

by

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Abstract

This study investigates the hypothesis that variations in symbol sign legibility distance can be accounted for on the basis of a sign's dependence upon high spatial frequency contours to convey critical information. Using digital image processing techniques, highway signs were blurred to remove all high spatial frequency information. A blur recognition threshold was established for each experimental sign by sequentially "deblurring" it until the observer could report the critical details defining its recognition criteria. Correlational analyses were then conducted to determine if legibility distance (collected in a previous study) could be predicted from the blur recognition threshold data. A significant correlation was observed between blur recognition threshold and sign legibility distance ($r = -0.734$, $N=12$, $p < 0.001$). That is, symbol signs with high levels of "blur tolerance" could be recognized at significantly greater viewing distances. These results support the application of new computer-assisted "recursive-blur" design techniques to optimize the effectiveness of symbol highway signs and related visual stimuli (see Schieber, Kline and Dewar, 1994).

Introduction

The U.S. Transportation Research Board (1988) has recommended that studies be conducted to determine if driver perception-response times could be accommodated better through improved design of symbol highway signs. Symbol (i.e., "pictorial") highway signs yield legibility distances which are - on average - twice as great as those achieved for text sign equivalents. However, the visual superiority of symbol signs is neither uniform nor universal. Some symbol signs are legible from 3-times as far away while other - poorly designed symbol signs - can be recognized at only half the distance of their textual counterparts (Jacobs, Johnston and Cole, 1975). In order to develop improved symbol signs, one must begin to account for this variability across signs. Once this is accomplished, rules for optimizing the legibility of symbol signs can be formulated and engineering-based improvements implemented.

Unlike text signs which are composed of a finite set of alphanumeric elements (e.g., 26 letters and 10 digits), symbol signs can assume countless shapes and permutations. As a result, rules and guidelines for optimizing their legibility have proved to be elusive. Schieber (1987) proposed that much of the variability in the legibility of symbol highway signs could be accounted for by the degree to which these signs depend upon high spatial frequency contours to convey critical information. This hypothesis implies that a symbol sign's legibility distance should be directly related to its blur recognition threshold. That is: (1) signs that can be recognized through high levels of experimentally-induced blur are those that do not depend upon high spatial frequency information to convey their meaning; and (2) these "blur tolerant" signs should be readable from significantly greater distances than signs with low degrees of blur tolerance. This

prediction is tested and supported in the study which follows. The demonstrated relationship between low blur recognition thresholds (i.e., good blur tolerance) and high legibility distances supports the use of recently developed "recursive-blur" design techniques for optimizing the effectiveness of symbol highway signs (Schieber, Kline and Dewar, 1994).

Method

The purpose of this study was to demonstrate the relationship between blur recognition threshold and legibility distance in a set of 8 experimental symbol highway signs. Each sign was digitally "blurred" to the extent that it was clearly unrecognizable. The sign was then gradually "deblurred" (in 20 equal steps) until the observer could report the "critical elements" which defined the sign's recognition criteria (see Kline, et al., 1990). The blur level at which sign recognition emerged was recorded as the blur recognition threshold. Some examples of progressively deblurred signs appear in Figure 1. Blurring was implemented using Fourier-domain image processing techniques on a desktop computer. Butterworth low pass filters with half-amplitude (3 dB) spatial frequency cutoffs of 1 through 20 cycles/image were employed. Representative samples of the low pass functions used to generate the filtered sign stimuli are depicted graphically in Figure 2. Sign stimuli were presented upon a high-resolution monitor and subtended a visual angle of approximately 6 degrees. Blur recognition thresholds were collected from 12 young adult observers with good visual acuity. Mean blur recognition thresholds were then correlated with average legibility distance data obtained from another group of 12 young adult observers using unfiltered versions of the same experimental symbol signs.

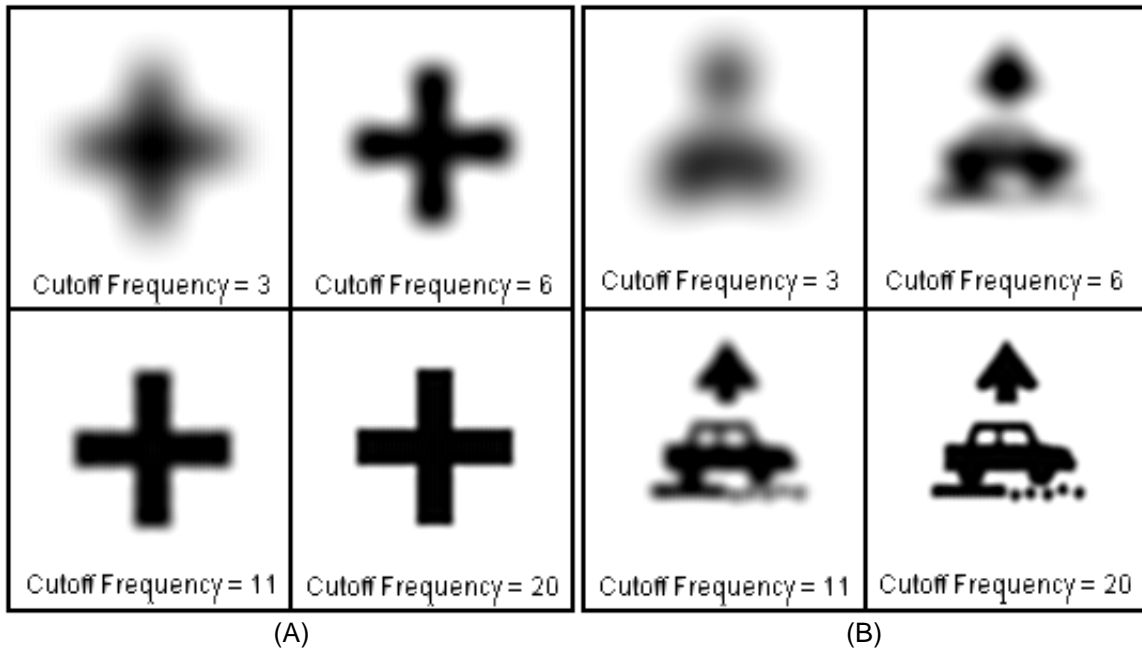


Figure 1.
Samples of progressively "deblurred" symbol highway sign stimuli.

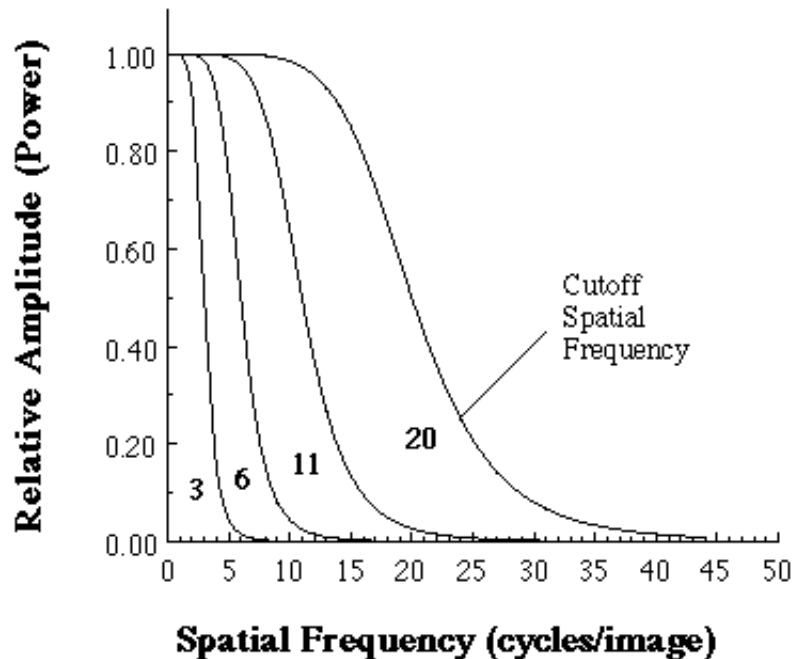


Figure 2.
Sample low pass spatial frequency filters used to blur symbol highway signs.

Results

Like legibility distance, blur recognition thresholds varied widely across signs (from 3 to 13 cycles/image). A simple regression analysis revealed that sign legibility distance was significantly related to blur recognition threshold ($r = -0.734$, $p < 0.001$). The nature of this relationship is apparent in Figure 3. In general, symbol signs which were the most resistant to blur (i.e., low blur recognition thresholds) tended to have the highest legibility distances. Figure 1B depicts a symbols sign which has a high blur recognition threshold (i.e., poor blur tolerance) and a concomitant poor legibility distance. The sign in Figure 1A, on the other hand, demonstrated both a high tolerance to the deleterious effects of computer-induced blur and an extraordinarily high legibility distance (In fact, the "crossroad" sign can be identified at a greater distance than any other sign in the *Manual of Uniform Traffic Controls and Devices*).

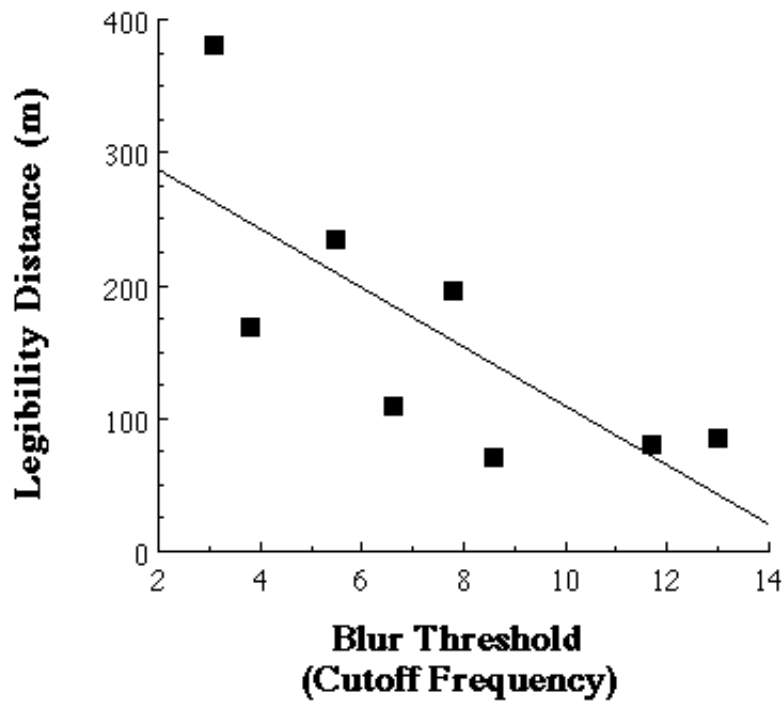


Figure 3.
Relationship between symbol sign legibility distance and blur recognition threshold.

Discussion

The negative correlation between blur recognition threshold and sign legibility distance strongly supports the hypothesis that good symbol signs are those which avoid reliance upon high spatial frequencies to convey critical information (as highly blurred signs contain little or no high spatial frequency contours). Blur tolerant symbol signs (i.e., blur recognition thresholds < 8 cycles/image) were readable at greater distances than signs with blur recognition thresholds greater than 8 cycles/image.

There is reason to suspect that the demonstrated relationship between blur recognition threshold and sign legibility distance obtained here might be strengthened given the implementation of additional experimental controls. For example, a stronger correlation would be expected if the blur recognition thresholds and legibility distance data had been obtained from the same sample of observers instead of from two separate groups. Another factor which could have weakened the observed statistical relationship was the failure to include the "conspicuity" border often found surrounding the symbol on a highway sign. Close placement of this surround to critical spatial details of a symbol sign has been demonstrated to result in reduced legibility distance as well as weakened blur tolerance. Current work in our laboratory is aimed at addressing both of these issues.

The findings reported above suggest that the legibility of signs with high blur recognition thresholds (poor blur tolerance) would be enhanced if those same signs were submitted to an optimization process which attempted to improve blur tolerance. Recent experimental evidence directly supports this notion. Schieber, et al. (1994) report that computer-assisted techniques for increasing the blur tolerance of symbol highway signs resulted in significant improvements in their legibility distance. Kline and Fuchs (1992) have reported similar results using a qualitatively similar optical blur technique.

Acknowledgment

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