Measurement and Analysis of Clutter in Electronic Displays

M.C. Lohrenz,[1] M.R. Beck,[2] J.G. Trafton,[3] and M.L. Gendron[1]
[1]*Marine Geosciences Division*
[2]*Louisiana State University, Baton Rouge*
[3]*Information Technology Division*

Introduction: Electronic geospatial displays are common—from aircraft moving-maps to handheld GPS devices. As new data sources become available, users are tempted to display everything of interest: digital charts, satellite imagery, weather data, etc. The ensuing clutter can impact a user's ability to access, interpret, and effectively use the displayed information. This paper presents a model of display clutter comprised of global and local components, which we compared with subjective clutter ratings and target search performance. Our results suggest strong correlations between our global clutter metric and subjective ratings, and between our local clutter metric and search performance.

Clutter Model: Rosenholtz et al.[1] define clutter as the state in which excess items, or their representation or organization, lead to a degradation of performance at some task. We describe global clutter as the total amount of clutter in a display, and local clutter as the amount immediately surrounding a target of interest (e.g., an airport symbol). We theorize a combination of global and local clutter impacts visual search (finding a target of interest). We predict visual search is largely affected by local clutter: if the area surrounding a target is cluttered, the target will be harder to find. However, if people perceive the entire display as cluttered (high global clutter), not only may they be less likely to use it, but they may search more slowly and carefully than if they perceive it as uncluttered (low global clutter).

We suggest clutter is a function of "color density" and "saliency" (Fig. 6). We define color density as a measure of how tightly packed similar-colored pixels are within an image. We compute this by clustering all the image's pixels in 3D (2D location and color), such that adjacent pixels of similar colors cluster together, and calculating the density of pixels in each cluster. Each cluster models a visually discernible "feature" on the display. We compute saliency as a weighted average of color differences among adjacent features (clusters). Greater color differences result in higher saliency; highly salient features are typically easier to detect. Lower color density suggests higher clutter, especially when saliency (between features) is high. When saliency is low, color density has less impact on clutter because features are less discernible. We propose the following clutter model:

$$\textbf{clutter} = 15(1-\textbf{color density})^* \exp[-6.3 \exp(-\textbf{saliency}/10)]-0.0002.$$

For very low saliencies, clutter remains very low, regardless of color density. When saliency is high, clutter becomes a function of color density only. For more information about this model, the reader is referred to Lohrenz and Gendron.[2]

Correlations with Human Perception and Performance: Participants completed two tasks (target search followed by subjective clutter ratings) to examine how well our model estimates clutter in one type of geospatial display: aeronautical charts. Fifty-five undergraduate students were shown 54 charts, displayed as 256-color GIF images. We made two copies of each chart: one with a target (elevation symbol) in a low local-clutter area (Fig. 7), and the other with the target in a high local-clutter area. We cropped each chart to a 60 × 60 pixel "snippet" centered on the target and ran the clutter algorithm on the snippet to compute local clutter. We considered four independent variables (2 × 2 × 3 × 3 factorial): global clutter (low, medium, high); local clutter (low, high); target shape (two types); and set size (4, 8, 16 distractors).

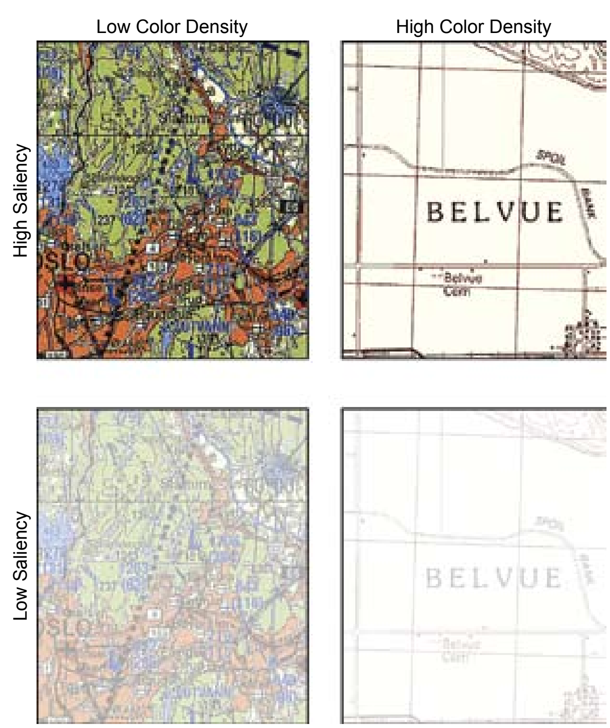

FIGURE 6
Electronic chart samples illustrating the impact of color density and saliency on clutter.

For the target search task, we recorded percent completed trials (a trial was terminated if the participant could not find the target after 45 seconds), percent correct, and reaction time. Local and global clutter affected all three search measures (shown in Table 1, which compares the actual clutter values—not binned—against performance measures). Both types of clutter slowed search time, as expected, with the effect of local clutter increasing as global clutter increased (Fig. 8(a)). Global clutter affected percent completed trials and percent correct only for high local clutter (Figs. 8(b) and (c)). Similarly, the effect of local clutter was largest when global clutter was high. Finally, there was a strong correlation (r = 0.77) between local clutter and reaction time.

In the subjective ratings task, which always followed the target search task, participants rated each chart from 0 (no clutter) to 9 (extremely cluttered). Results for low and high local-clutter charts are identical (Fig. 8(d)) indicating only global clutter had an effect on subjective clutter ratings, as expected. There was a very strong correlation (r = 0.86) between the global clutter metric and mean ratings. Neither target type nor set size had any effect.

Conclusions: This paper presents a model of clutter for complex geospatial displays. Our results suggest saliency and color density are important components of clutter. Our global clutter metric correlates very well with subjective ratings of display clutter. Both global and local clutter significantly impact target search performance, with the effect of local clutter increasing as global clutter increases.

Acknowledgments: This work was sponsored by NRL (6.2 Program Element 602435N). We thank Geary Layne and Stephanie Myrick for their assistance. We thank the Louisiana State University Psychology Department for computer resources and students to participate in the clutter experiments.

[Sponsored by NRL]

References

[1] R. Rosenholtz, Y. Li, J. Mansfield, and Z. Jin, "Feature Congestion: A Measure of Display Clutter," *SIGCHI 2005*, Portland, OR, pp. 761-770, April 2005.

[2] M. Lohrenz and M. Gendron, "A 3D Clustering Algorithm to Model Clutter in Electronic Geospatial Displays," *J. Management and Engineering Integration* **1**(1), Summer 2008 (in press). ★

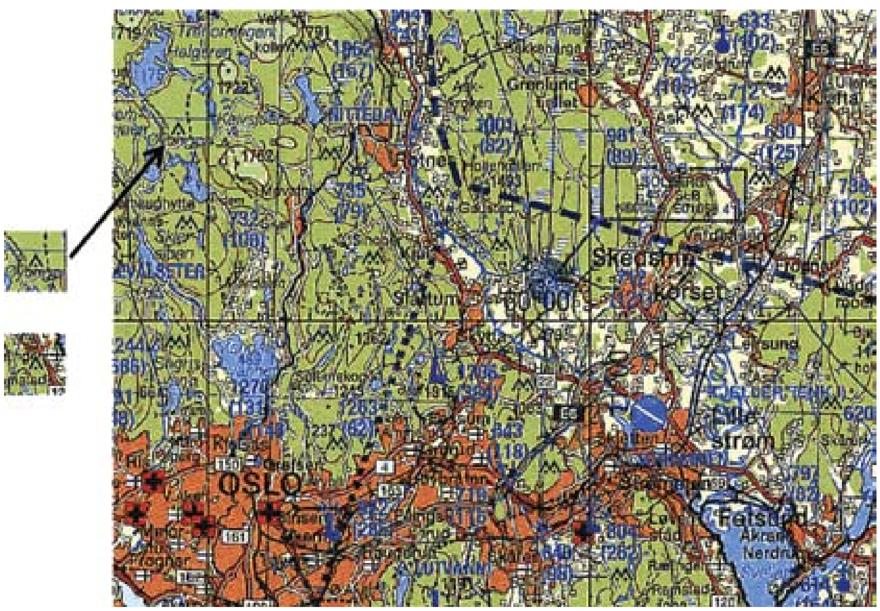

FIGURE 7
High global-clutter chart with low (top left) and high (bottom left) local-clutter targets. There were two copies of each chart, one for each local clutter condition. (The chart shown is the low local-clutter version, so only the low local-clutter target is present in this chart).

TABLE 1 — Individual Effects on Target Search Performance

Independent Variable	Mean RT		% Completed		% Correct	
	t ratio	p	t ratio	p	t ratio	p
Local clutter metric	12.38	<0.0001	–7.57	<0.0001	–7.90	<0.0001
Global clutter metric	7.85	<0.0001	–5.31	<0.0001	–5.68	<0.0001
Target type	1.48	0.14	–2.17	<0.05	–2.00	<0.05
Set size	–0.85	0.40	0.70	0.48	1.02	0.31

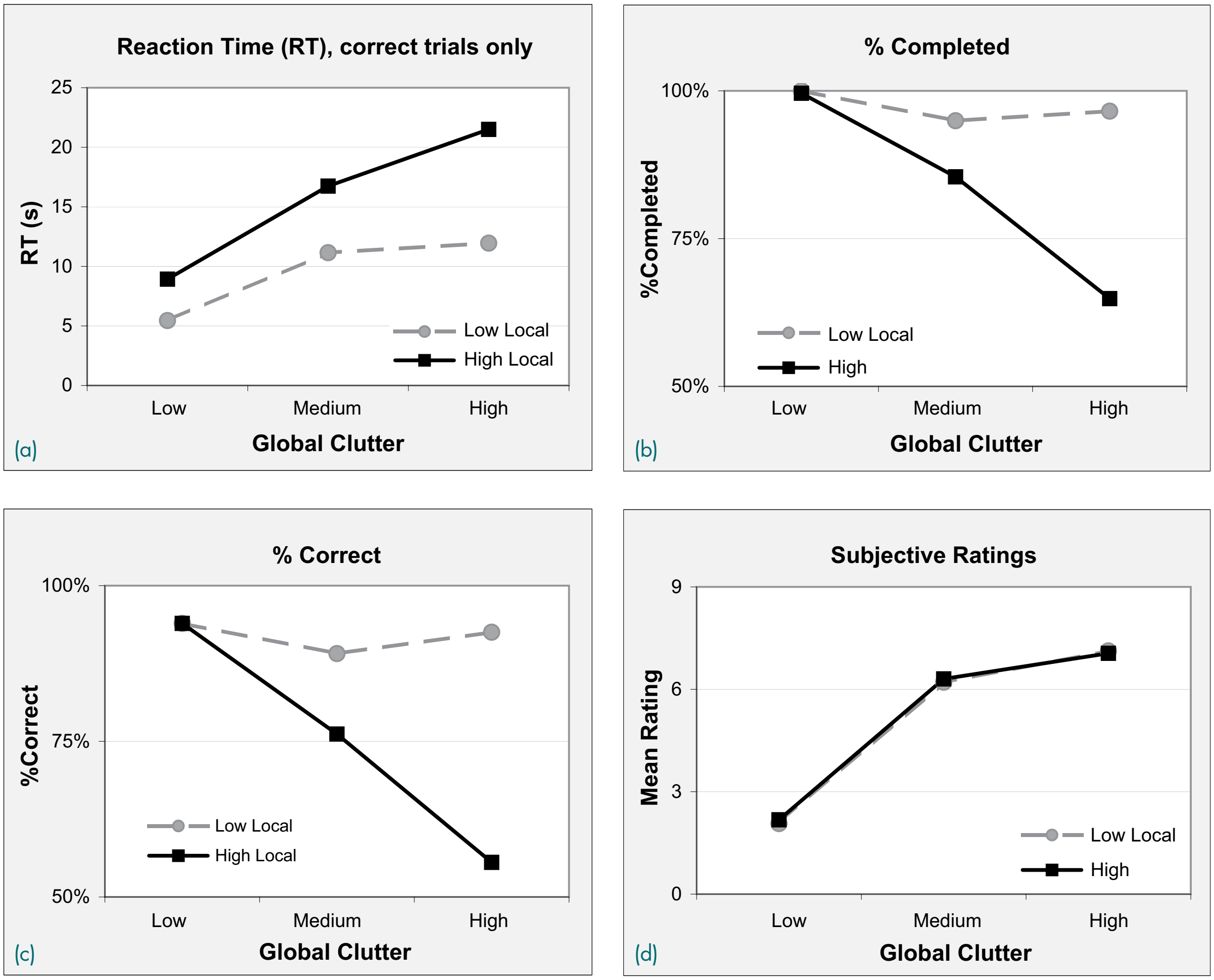

FIGURE 8
(a) Only global clutter affected subjective clutter ratings. Local clutter had no effect. (b) Both global and local clutter slowed reaction time. (c-d) Local clutter had a greater effect than global clutter on the number of trials participants were able to complete (including both correct and incorrect trials) and the number of correct trials. In both (c) and (d), global clutter only had an effect if the target was in a high local-clutter region.