The Time Course of Visual Completion Measured By Response Classification

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BACKGROUND

Several studies have found evidence that people rely upon both occluded & illusory contours when performing various visual discrimination tasks (e.g., Murray et al., 2001; Ringach & Shapley, 1996; Sekuler & Palmer, 1992). Results from these studies have also suggested that it takes the visual system a certain amount of time to build up a completed representation.

Recent studies have used a technique called response classification to pinpoint the locations in images that people are using when they are asked to discriminate amongst different spatially-occluded contours (Gold et al., 2000). Here, we used this technique with dynamic noise to examine the spatiotemporal aspects of the completion process.

METHODS

Observers

• Two males & one female
• Ages 28, 31, & 27, respectively
• Two were native

Stimuli

• Fat & thin Kanizsa figures
• Inducers rotated by ±1.75°
• Inducer radius: 16 pixels (0.34°)
• Distance between centers of adjacent inducers: 64 pixels (1.36°)

Noise Fields

• High contrast Gaussian white noise field
• a = 25% contrast
• 100 x 100 pixels (2.13° x 2.13°)

Staircase

Signal contrast was varied across trials with an adaptive staircase to maintain 71% correct performance throughout the experiment.

Ideal Observer

Ideal observer performance was measured in each condition by Monte Carlo simulations of the ideal observer's classification images, defined by both illusory and occluded contours (Gold et al., 2000). We had observers discriminate between fat & thin Kanizsa squares in spatiotemporal noise, and classified the human observer's responses according to the course of the 43 stimulus frames. If there is a time course for visual completion, we would expect to see a gradual divergence between the ideal observer's classification images in the Real condition and human classification images in the Real condition, as the time course of normal visual processing of real contours.

For purposes of visualization, the classification images were smoothed over space & time by a spatiotemporal convolution kernel (f = 0.25% contrast). Samples of the classification movie taken at 59 ms intervals are shown in Figure 4 for each observer in each condition.

PERFORMANCE

Contrast energy thresholds & efficiencies are plotted for each observer in each condition in Figures 1 & 2, respectively.

Efficiency is defined as the ratio of the ideal to human contrast energy thresholds in each condition.

Note that, for all observers, efficiency was greater in the Illusory condition to the Real condition.

To quantify the changes in the classification images, we compared the human observers' classification movies with a classification image derived from the ideal observer's classification templates in the Illusory & Real conditions. Ideal observer classification templates (shown at right) were generated for both the Real & Illusory conditions. The top figure shows the raw classification templates, and the bottom figure shows the templates after being smoothed by the same spatiotemporal convolution kernel as was used with the human classification images. These templates indicate the regions of the stimulus that contain task information for each task. In the Real condition, there is information distributed across the entire perimeter of the square. In the Illusory condition, there is only information at the edges of the inducers. When subtracting the Illusory template from the Real template to form a Difference template, we are left with only the regions between the inducers — these representing the locations corresponding to the Illusory & Real contours.

For each observer & condition, every frame in the human classification movie was cross-correlated with the Difference template. Given the temporal changes that we observed in the classification images, we would expect to find a more gradual increase in correlation for the Illusory than for the Real condition for observers CB & ES. Figure 5 shows the correlations between the human classification images & the Difference template at each frame in time.

SUMMARY, CONCLUSIONS, & FUTURE DIRECTIONS

We had observers discriminate between fat & thin Kanizsa squares in spatiotemporal noise, & found that Illusory contours emerge in observers' classification images as early as 47 ms & are fully present by about 120 ms. These results are relatively consistent with previous estimates of the time course of completion, e.g. Ringach & Shapley (1996): 120-170 ms; Sekuler & Palmer (1992): 100-200 ms; Murray et al. (2001): 46-114 ms.

Although observers participated in 30,000 trials per condition, the classification movies are still quite noisy. This is consistent with the results of Ringach & Shapley (1996), who found that signal strength in spatiotemporal classification images is highly limited by internal noise at high noise frame rates. Therefore, one possible way to reduce the noise of our classification images would be to increase the duration of each noise frame. An alternate approach would be to present the stimuli in static noise for varying stimulus durations & interrupt completion with a mask (Ringach & Shapley, 1996). We are currently exploring these possibilities.

REFERENCES & ACKNOWLEDGEMENTS


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