AIR TRAFFIC CONTROL WEATHER RADAR DISPLAYS: VALIDATION OF A MASKING METRIC FOR PREDICTION OF TEXT BLOCK IDENTIFICATION

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Background: The Federal Aviation Administration is evaluating the potential benefits of weather information overlaid on the Terminal Radar Approach Control (TRACON) radar display. The study's objective was to validate a background masking metric to assist display designers to identify good color combinations for an air traffic control weather radar display. **Methods:** A uniform gray pattern and two weather radar displays were used as the background for randomly selected aircraft data text blocks positioned in eight fixed locations around a central location. The observers' task was to search for the data text block that matched the text block presented in the central location. Four text contrast levels were used for the uniform background and two levels were used for each of the weather radar backgrounds. **Results**: Percent correct responses and response latency were plotted as a function of the equivalent contrast based on a simple luminance contrast metric. **Conclusions**: The metric is a fairly good predictor of the masking of the text blocks by the colored weather map backgrounds.

INTRODUCTION

The Terminal Radar Approach Control (TRACON) air traffic controller is responsible for the safety of arriving and departing aircraft within the terminal area. The air traffic controller must ensure aircraft are spaced no closer than 1,000 vertical feet and 3, 4, or 5 lateral separation, depending upon aircraft size (Wickens, Mavor, and McGee, 1997). For many years, the Federal Aviation Administration (FAA) has introduced new technologies and procedures to be integrated into the National Airspace System (NAS) to improve air traffic controller performance and minimize users' risk. One such program, called the Integrated Terminal Weather System (ITWS), provides TRACON controllers short-term forecasting of hazardous weather patterns. The purpose of this study is to develop a color discrimination model to assist human factors professionals in determining the optimal assignment of look-up-table values to ITWS objects overlaid on the TRACON radar display.

The ITWS integrates FAA and National Weather Service sensors to provide TRACON controllers a weather model that can predict hazardous weather conditions 30 minutes into the future (Cole and Wilson, 1994). This weather model can predict storm motion, leading edge of storms, gust fronts, microbursts, windshear, tornado, wind speed, and lighting strikes. The ITWS data will be overlaid on the Standard Terminal Automatic Replacement System (STARS) or the Automated Radar Terminal System (ARTS) color display. The depiction of weather symbols size or color has not been determined nor has the FAA finalized the procedures on how the TRACON controller will utilize this information. Currently, the air traffic controller, TRACON or en-route, does not separate aircraft from weather, but they can and should provide weather advisories to flight crews. The flight crew may request a heading or altitude change based upon the weather advisory, but it is the responsibility of the flight crew to avoid hazardous weather.

The TRACON radar display contains aircraft data blocks (aircraft's call sign, mode C altitude for equipped aircraft, and ground speed) and terminal area markers such as ground hazards, approach and departure routes, and navigational fixes (Wickens, Mavor, and McGee, 1997). Currently, controllers use the Full Digital ARTS Display (FDAD) monochrome monitor, but the FAA is replacing these monitors with the STARS or ARTS color displays. Both the STARS and ARTS color display can support ITWS software, but there is no consensus as to the best method to overlay weather information on the radar display.

Scharff, Hill, and Ahumada (2000) found that the readability of text on textured backgrounds can be predicted by a simple luminance masking metric, which computes an equivalent contrast on a uniform background. The metric was borrowed from contrast gain control masking models and has the form

$$C_E = C/(1 + (C_{RMS}/C_2)^2)^{0.5} ,$$

where C_E is the equivalent text contrast, C is the text luminance contrast, C_{RMS} is the root mean square luminance contrast of the background alone and C_2 is a luminance contrast masking threshold.

Our hypothesis is that this equivalent luminance contrast metric will predict the equivalent search accuracy and latency performance in our text block identification task.

METHODS

Observers: Three observers (26, 35, and 37 years of age) had normal or corrected-to-normal visual acuity, and two of the three observers had normal color vision as tested with pseudo-isochromatic plates. Informed consent was obtained from all observers. All observers but one (first author who was red/green color deficient) were naïve to the experimental hypothesis.

Apparatus: Stimuli were displayed on a 19” color CRT monitor at a frame rate of 85.0 Hz. Observers viewed the screen from a distance of approximately 0.75 meters, giving 53.8 pixels per degree of visual angle in the horizontal direction and 45.7 pixels per degree vertically. The screen was 26.2 by 20.4 degrees (1024 by 768 pixels).

Stimuli: The stimuli were presented using the red, green, and blue guns of a color CRT. At their maximum level, the individual guns had the luminance (Y) and CIE color chromaticities (x, y) shown in Table 1.

Gun	Y	X	y
Red	13.5	0.603	0.356
Green	43.1	0.282	0.612
Blue	5.22	0.143	0.063

Table 1. Luminance (cd/m^2) and chromaticity values for the three CRT guns.

The screen background was set to a neutral gray with equal contributions (128/255) from the three guns. Calibrations were done with a Minolta CS-100 colorimeter. Each image had fewer than 20 colors, so each of the colors in the image and the grays used in the text were calibrated individually.

The background images were 20.05 by 15.58 degrees (776 by 593 pixels). The uniform background had a luminance of 4.44 cd/m^2. The wind shear and gust front had mean luminances of 3.2 and 0.83 cd/m^2, respectively. The root mean square contrasts for the map backgrounds were 1.53 and 3.56, respectively. The text contrasts relative to the background mean luminance were: 0.11, 0.23, 0.55, and 0.86 for uniform; 1.03, 1.71, for wind shear; and 2.46, 4.58 for gust front.

Adobe PhotoshopÒ version 5.5 was used to generate the data blocks. The data block image font was Letter Gothic MT size 10 points with tracking set at –70.

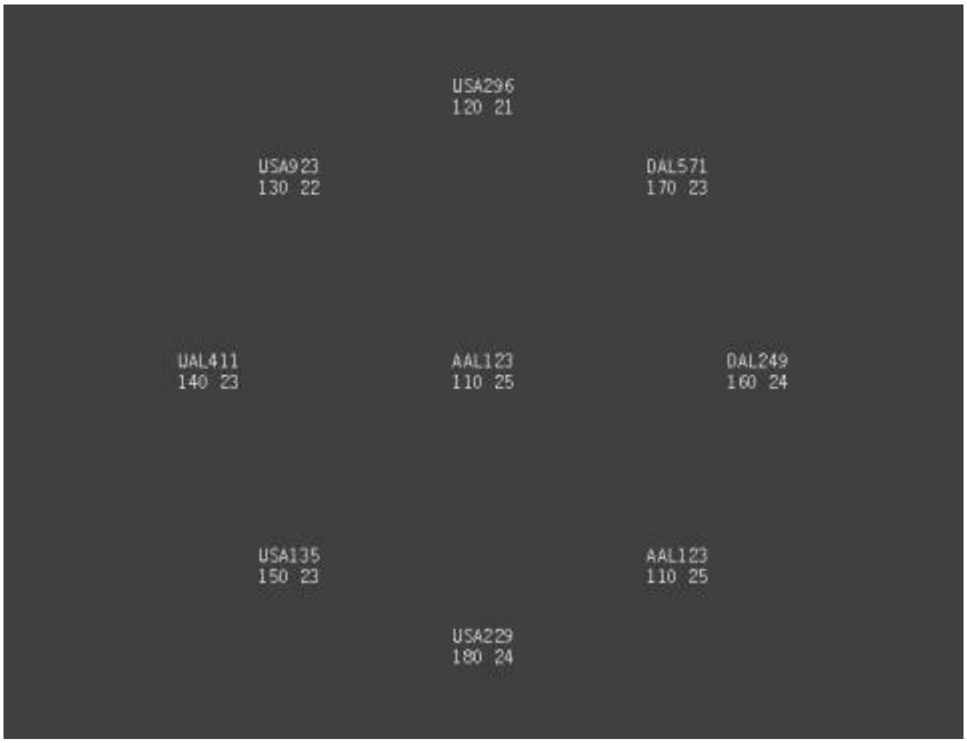


Figure 1. Uniform noise pattern. The test stimulus consisted of randomly selected aircraft data blocks positioned in one of eight locations 1200, 0130, 0300, 0430, 0600, 0730, 0900, and 1030 respectively at a distance of 5.8 degrees from the center. The subject's task was to identify the position of the surround data block to the center data block.

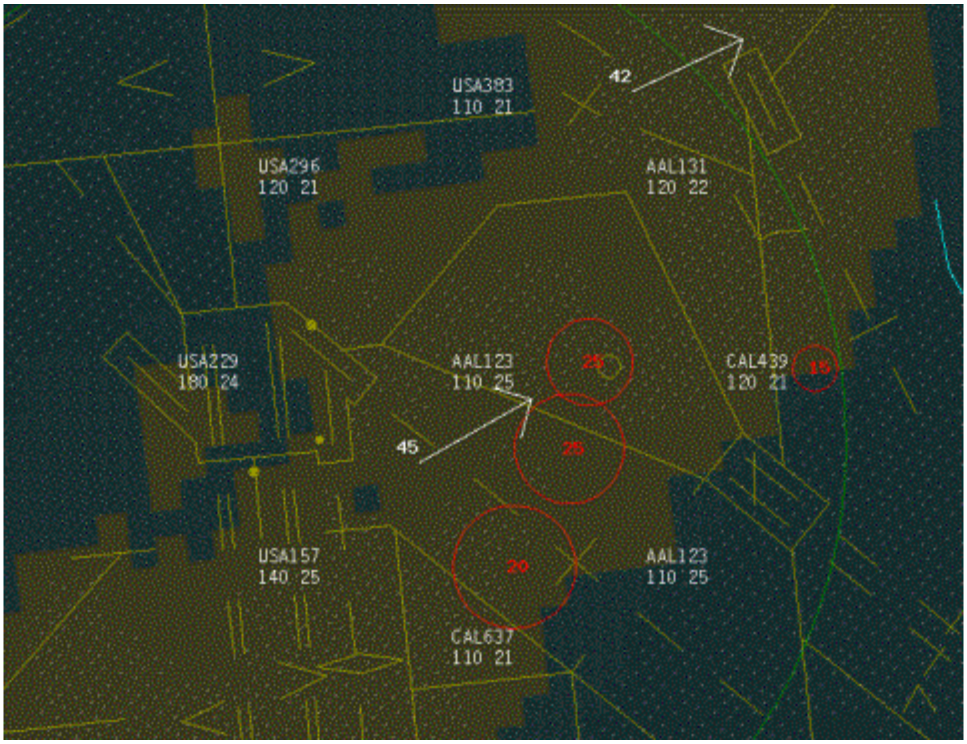


Figure 2. A simulated wind shear weather pattern overlaid on an air traffic control radar monitor display. The test stimulus similar to the uniform noise pattern consisted of randomly selected aircraft data blocks positioned in one of eight locations 1200, 0130, 0300, 0430, 0600, 0730, 0900, and 1030 respectively at a distance of 5.8 degrees from the center. The subject's task was to identify the position of the surround data block to the center data block.

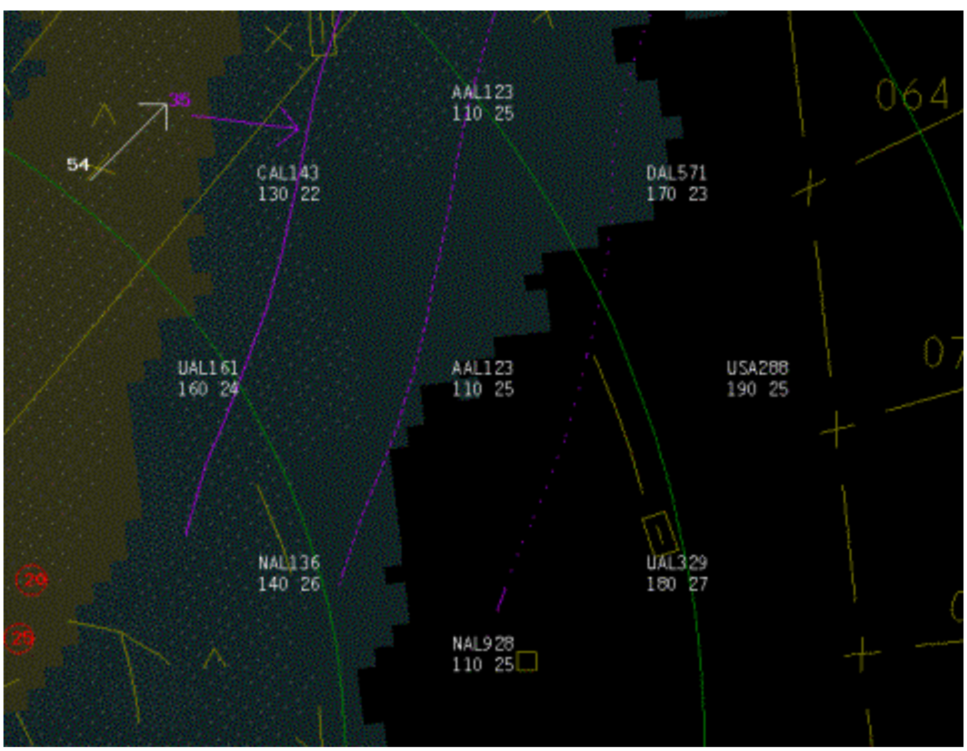


Figure 3. A simulated gust front weather pattern overlaid on an air traffic control radar monitor display.

Procedure: The observers' task was to search a simulated air traffic control weather radar image for a specific aircraft data block. Each trial began with a fixation cross located in the center of the background image. After 500 milliseconds, the fixation cross was replaced by a stimulus image which remained visible for 8.5 seconds or until the observer's response. The stimulus image contained a data block located in the center of the screen with an additional eight data blocks positioned 5.8 degrees from the center. The observer's task was to provide a manual response indicating the location of the surrounding data block that matched the center data block. Observers were asked to press '1', '2', '3', '4', '6', '7', '8', '9' on the numeric keypad of a standard PC keyboard if a target was located in the '0730', '0600', '0430', '0900', '0300', '1030', '1200', and '0130' respectively. The participant began the next trial by pressing '5'. For each condition the background scene – either the uniform, wind, or gust image without text blocks – remained visible throughout the 60 trials thereby avoiding any secondary masking effects due to switching between no scene to scene for each trial. Error rates and reaction times (RTs) were recorded. Observers were asked to provide responses as quickly as possible while maintaining a high level of accuracy. Each observer completed 3 replications of the experiment. Each replication consisted of eight blocks (4 text contrasts on the uniform background, 2 text contrasts with the wind shear mask, and 2 text contrasts with the gust front mask) of 20 trials each, for a grand total of 480 trials. Each subject received a different order of blocks. Data block location was not a factor, thus on some blocks target location was not uniformly distributed across location. Feedback was provided following an incorrect response. Individual trials were separated by intervals of approximately 1000 milliseconds. Observers were allowed periodic rest throughout the experimental session.

RESULTS

Figure 4 shows the average proportion correct identifications for the 3 observers a function of the text luminance contrast adjusted by the masking metric with a masking threshold of $C_2 = 0.5$ for each of the three backgrounds. Figure 5 shows individual data for the three subjects which illustrates the same pattern as the average data. Figure 6 shows the average response times in the same format and figure 7 displays each subject's data which shows a similar pattern to the average data. The accuracy appears to have reached asymptote for a contrast of 0.23 on the uniform background, but the response latencies continue to improve with contrast. A masking threshold was estimated for each of the four masked conditions separately from the response latency data. These predictions were obtained using linear interpolation on the latency data to find the uniform background contrast that would give the latency obtained with the mask background. The threshold of 0.5 is the average of the four estimates. The metric with this threshold gives an equivalent contrast that is too low for the wind shear mask conditions and too high for the gust front mask conditions.

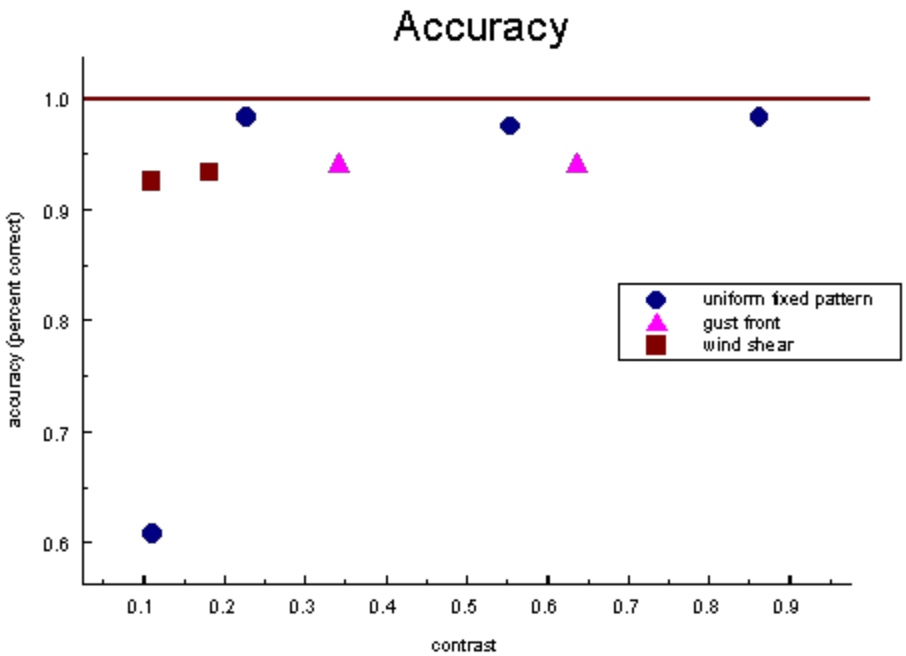
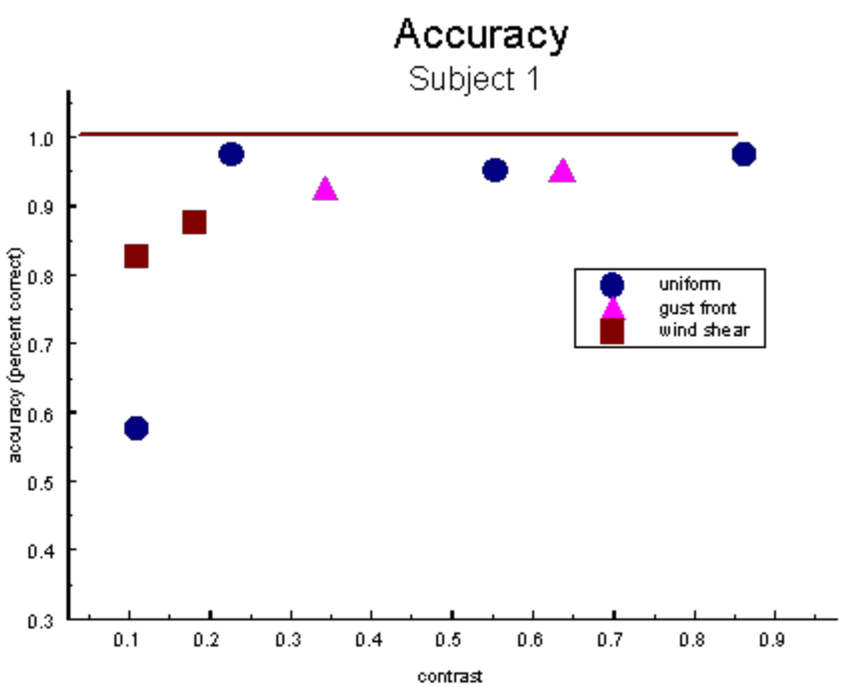
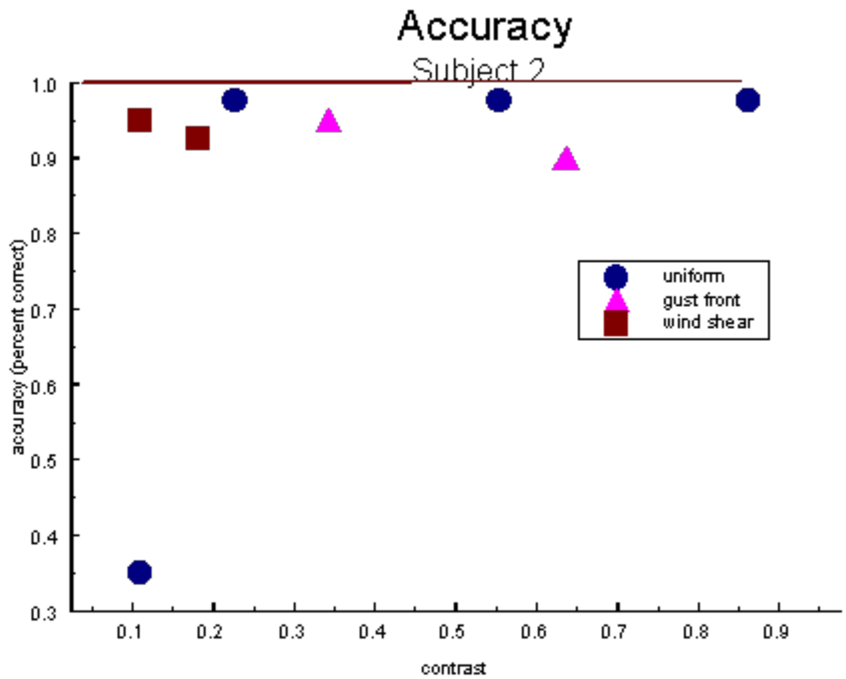


Figure 4. Mean accuracy for three subjects. The wind shear predicted mask values were nearly identical to the behavioral wind shear mask values, while the gust front predicted values were slightly different than the behavioral values.





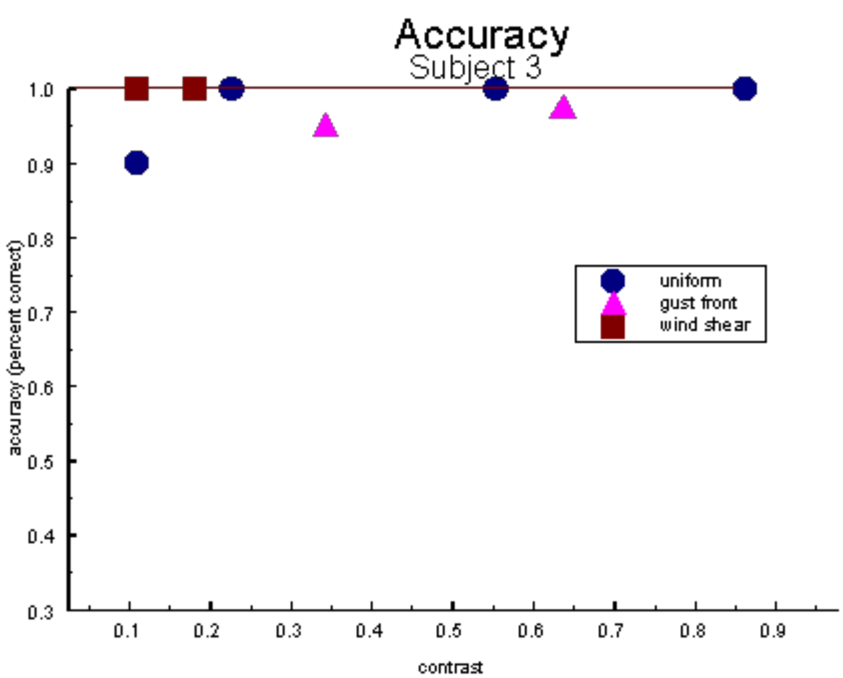


Figure 5. Three subjects' individual accuracy performance results for the uniform fixed pattern, wind shear and gust front conditions.

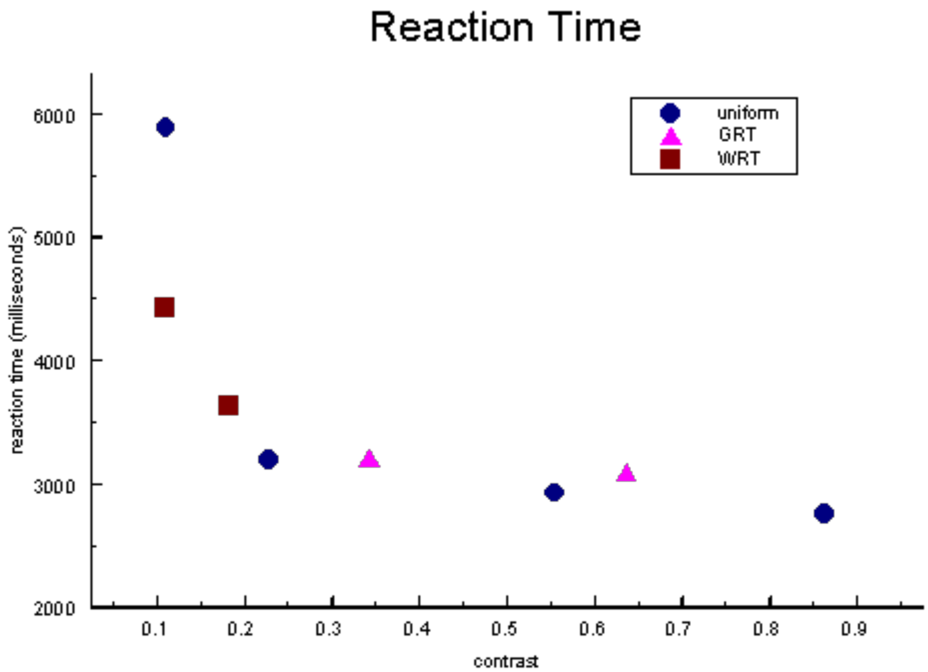
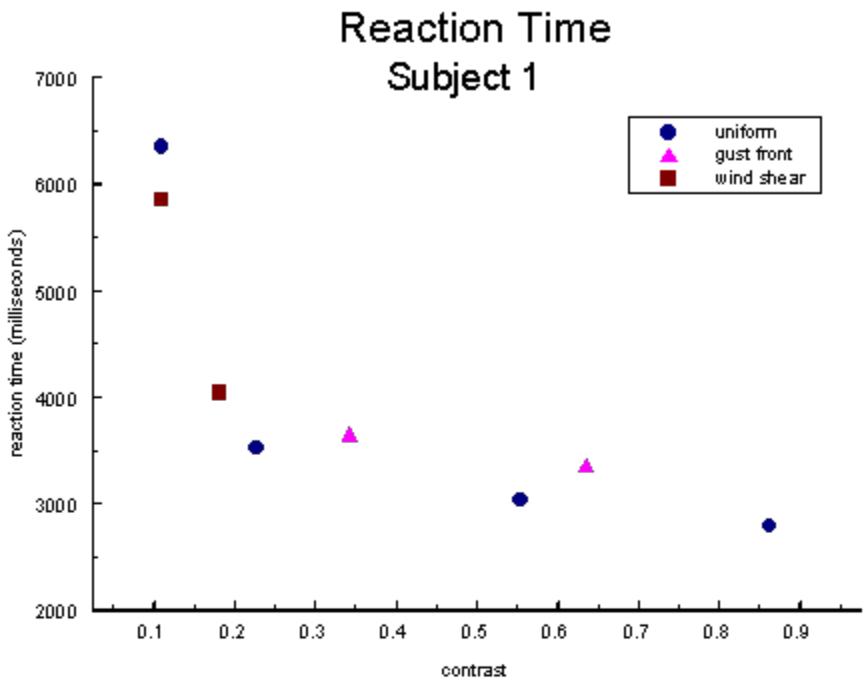
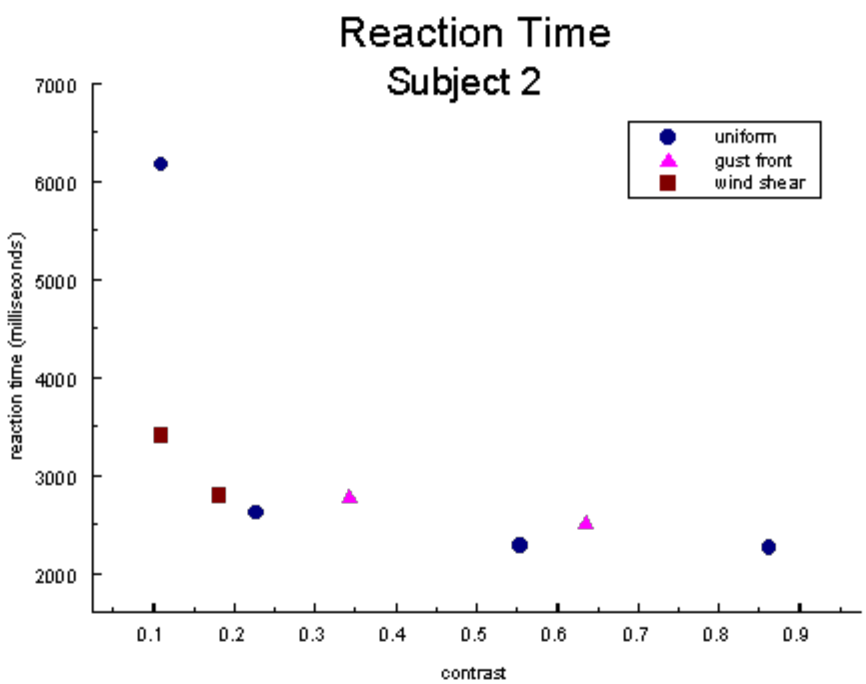


Figure 6. Mean reaction time for three subjects. The gust front predicted mask values were very similar to the behavioral gust front mask values, while the wind shear predicted values were slightly different than the behavioral values.


Reaction Time
Subject 1
uniform
gust front
wind shear
reaction time (milliseconds)
7000
6000
5000
4000
3000
2000
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
contrast


Reaction Time
Subject 2
uniform
gust front
wind shear
reaction time (milliseconds)
7000
6000
5000
4000
3000
2000
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
contrast

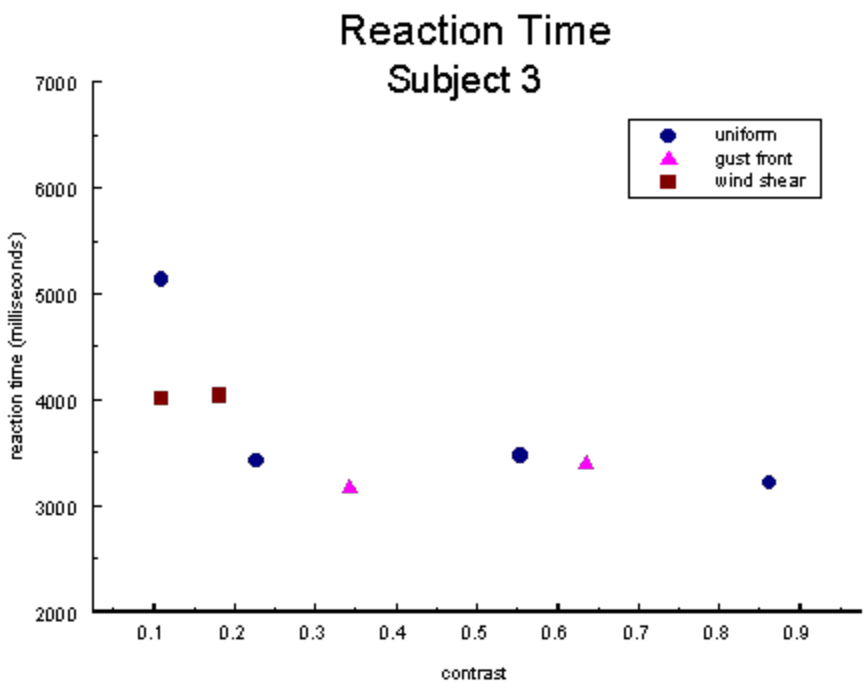


Figure 7. Three subjects' individual reaction time performance results for the uniform fixed pattern, wind shear and gust front conditions.

CONCLUSIONS

The luminance contrast metric appears to do a fair job of predicting the results of this experiment with the masking threshold estimated from the experiment. This metric would be much more useful if the masking threshold were close to that found in other studies, such as that of Scharff and Ahumada (2000). They used a value near 0.05 rather than 0.5. There are several reasons that the metric might not be doing better here. The metric is designed for predicting the effects of spatially homogeneous maskers, it is not designed to predict the effects of variations in the mean luminance, which are pronounced in the wind shear mask and which was better fit by an even larger value for the masking threshold. The metric as implemented also does not take into account the masking effects of the text blocks themselves, which would be expected effectively to raise the masking threshold.

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