What makes a letter?

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E. Kim (1999) *What makes a letter?* Intel Science Talent Search.
http://psych.nyu.edu/pelli/#intel

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LAYMAN'S SUMMARY AND ABSTRACT

Closely spaced objects tend to be seen as a group. I tested the extent to which this Gestalt Law of Proximity plays a role in the identification of letters made up of many nonoverlapping marks. The alphabet used was rendered by tracing the strokes of the letters in the Sloan eye-chart alphabet, but drawing the strokes as a series of Gabor marks (sinewave gratings). Each grating has a spatial frequency, the number of cycles per degree of visual angle.

Majaj et al. (1999) showed that isolated gratings are detected by visual channels tuned to the grating frequency, f channel = f, but that letters are identified by channels nonlinearly related to the letter frequency f channel = f ^2/3. I reasoned that a letter made of gratings were sufficiently close together, but would disintegrate into a collection of gratings if the grating are to far apart to be seen as a group. My experiment varied the mark to mark spacing, and the spatial frequency of each mark. I measured the observer's channel frequency for each case. Plotting channel frequency as a factor of grating frequency, I found a log-log slope of 2/3, indicating a letter channel, when the spacing was 1, and a slope of 1, indicating a grating channel, when the spacing was 4. This shows that grouping by proximity determines whether we see marks as a letter.

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LITERATURE RESEARCH

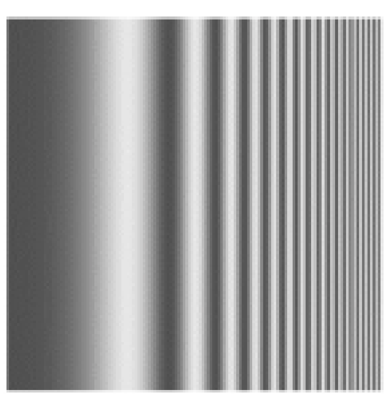
GESTALT

Field, Hayes, and Hess (1992) displayed “snakes” of many grating patches arranged along a curved path, weaving among randomly placed patches. This was done to test good continuation of the patches. The task was that the observer was shown two stimuli, one having only randomly placed patches, and the other having a “snake” amidst the random patches. They varied the orientation of the patches and the curve of the snake. They discovered that an observer’s percent correct would fall if the patches deviated more than 45 degrees from the path of the snake.

GRATINGS

Sinusoidal gratings, are useful in characterizing visual channels. A sinewave grating has alternating dark and light bars fading into one another (Cornsweet, 1970). (Figure 1) The human visual system contains numerous visual channels, which are tuned to various spatial frequencies. *Spatial frequency* is the number of lines (dark or light bars) per degree of visual angle.

Figure 1: sinusoidal grating (Cornsweet, 1970)



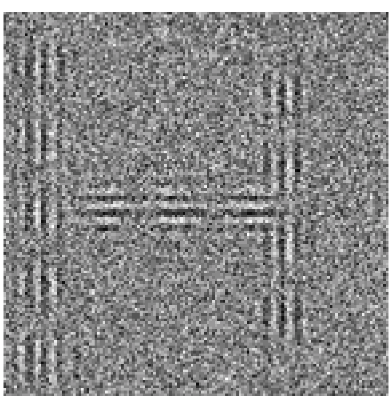
CHANNELS AND MASKING

A *channel*, is a visual mechanism tuned to a particular spatial frequency. Physiologically, it corresponds to a collection of neurons with identically shaped receptive fields. Channels help us identify the object that an observer is viewing, though it is not yet known how observers identify objects. Solomon and Pelli (1994) wanted to see if channels found with gratings are used to identify letters. They used critical band masking to determine which frequency the observers channel was tuned to. This technique applies high-pass and low-pass noise to determine the tuning function of the channel frequency under letters of one degree. They found the same channel tuning for band-pass letters and gratings. This means that as long as their spatial frequency is the same, their identification tasks for letters and gratings have the same channel frequency. The paper states an assumption that the human visual system would utilize channels that best fits the signal to noise ratio, so that the letter can be viewed more clearly. But this assumption was not correct for higher and lower frequency channels were less effective or completely unable to identify one degree letters.

EXPERIMENTAL DESIGN

In the first part of the experiment (letter identification under varying markspacings at a carrier frequency of 1 cycle / degree), an observer was briefly shown a faint letter (the signal) in visual noise (Figure 2) and was then asked to select the correct letter from a displayed group of all the letters. The observer 1 m from a gamma-corrected grayscale monitor and fixated on a point that was displayed at the center of the monitor. After starting the program, the monitor would flash a letter (the signal) 200 ms. The letter subtends a visual angle of 4 degrees. The monitor then displays all the possible letters in that alphabet. The observer used a mouse to select the letter from that display that he thought corresponded to the signal. Each run consists of 160 trials under visual Gaussian noise, and 160 trials without noise under that markspacing; usually totaling over 3,600 trials per each markspacing of 24, 36, 48, 72, and 96. (Figure 3 and 4) Correct responses were rewarded a beep.

Figure 2: a letter in visual noise



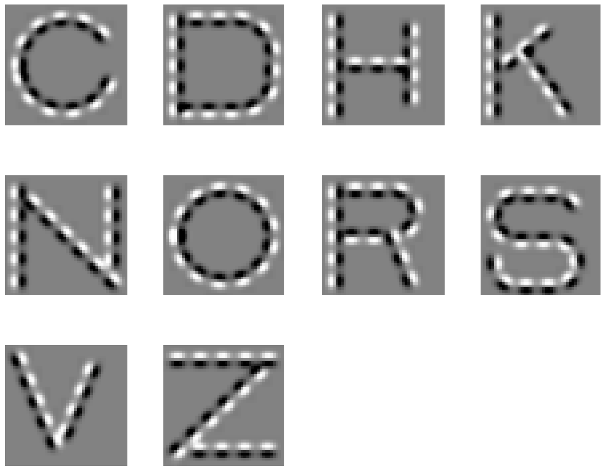


Figure 3: "snake letters" with mark spacing of 1

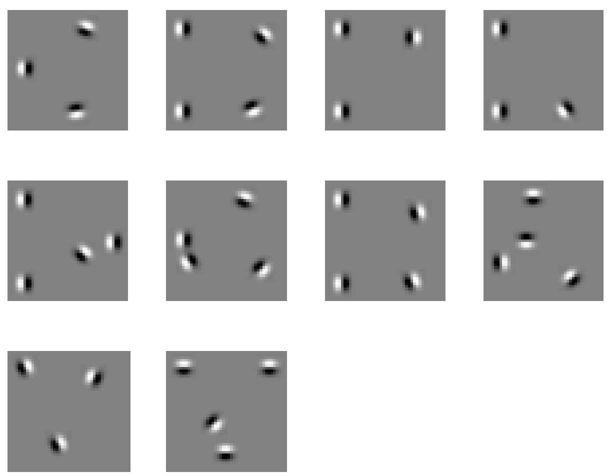


Figure 4: mark spacing of 4

In the next part of the experiment (letter identification under varying frequencies, spatial frequencies, and markspacings), the setup for the experiment was the same as it was in the first part of the experiment. Before starting the program, set values were placed on spatial frequencies (0, 1, 2, 3, 4, 5, 8, 9, 10, ∞) under high-pass and low-pass filtered Gaussian noise. Each run consisted of 40 trials in high-pass noise of a specific cut-off frequency and 40 trials under low-pass noise of a specific cut-off frequency, usually totaling over 400 trials per set conditions. The fixed conditions were frequency of 1 cycle / deg at a markspacing of 1, a frequency of 1 cycle / deg at a markspacing of 4, a frequency of 5 cycles / deg at a markspacing of 1, and a frequency of 5 cycles / deg at a markspacing of 4. The values for the spatial frequency varied after the first set of 400 trials from each of the four conditions just mentioned; varying on the basis of the greatest error shown on the carrier frequency by cut-off spatial frequency graph. Correct answers were rewarded with a beep.

In this experiment, the critical band masking technique, which is applying high and low pass noise to find the tuning function of the channel frequency under letters of one degree was applied. The identification task of high-pass and low-pass maskings through channels appear close together when graphed, which means that it is difficult to identify one degree letters in low and high channel frequencies. In this experiment, the observer viewed letters in both high-pass and low-pass noise under varying cut-off spatial frequencies. There is a major difference that has to be pointed out between high-pass and low-pass noise. High-pass noise contains only the high frequencies. Low-pass noise screens out all frequencies except the low ones. Both high-pass and low-pass noise are needed to create its threshold curves, tuning functions, and the channel frequency as a function to a line frequency graph. (Figures 5 and 6)

Majaj et al. (1998) define channel frequency as the geometric mean of the center frequencies of the low-pass and high-pass channels. Figure 7 shows that the

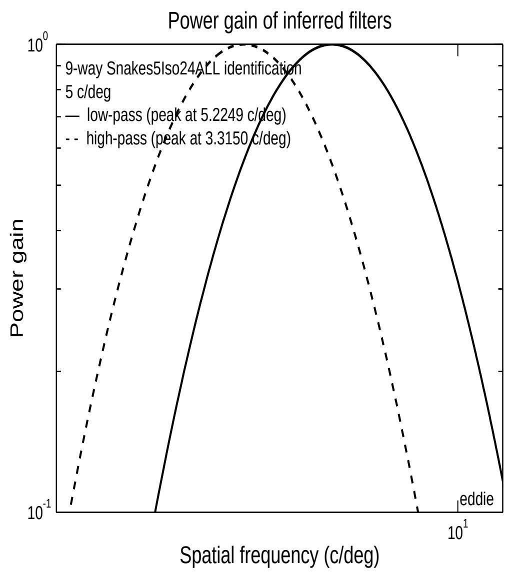


Figure 5: tuning function for markspacing 24, at 5 cycles/deg

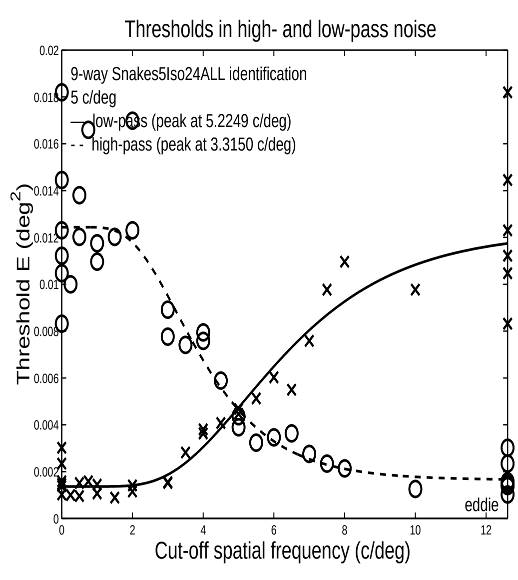


Figure 6: threshold energy as a function of noise cutoff frequency for markspacing 24, at 5 cycles/deg

channel frequency is proportional to letter frequency, with a log-log slope of 2/3. *Letter frequency* is the average number of lines that crosses across all the letters, divided by the letter's average width. This will produce a value in lines/degree. Letter frequency helps determine the center frequency of the channel used to identify letters. For the Sloan alphabet the letter frequency is 1.7. Binary *signals* are unfiltered letters. But for filtered letters, it creates a slope close to the unit slope of one on the same graph.

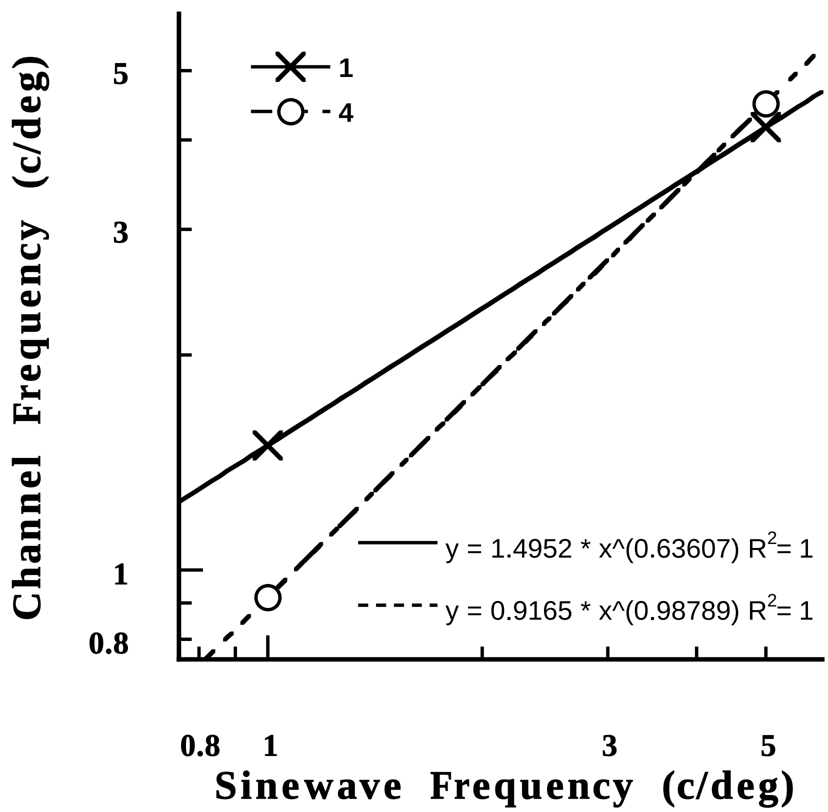


Figure 7: channel frequency as a function of sinewave frequency

RESULTS

Critical-band masking was used to measure the observer's channel frequency for each markspacing and carrier frequency. The data were plotted as threshold energy as a function of the cut-off spatial frequency. The fitting program assumed a parabolic shape for the channels seen in Figure. Plots were plotted as channel frequency as a function of letter frequency, to show the difference of slope between band-pass letters of markspacing 1 and markspacing 4. The slope of the markspacing 4 alphabets is close to one, matching the slope Majaj et al. found for sinewave gratings. The slope of the markspacing 1 is close to a unit slope of 2/3, matching the slope they found for letters. (Figure 7)

DISCUSSION

Our results indicate that since letters with a markspacing 4 has the same slope as does gratings, these letters, when viewed by an observer, are seen as gratings. In contrast, the results for letters with a markspacing of 1 does not have the same slope as does gratings but, has a slope similar to a value of 2/3. Therefore, when these letters are viewed by an observer, they are seen as unfiltered letters; even though those letters are actually filtered. My hypothesis that if the gratings are too far apart they won't be seen as a letter is confirmed.

FUTURE RESEARCH

It would be worthwhile extending the present results to other letter sizes and alphabets.

APPLICATIONS

Studying how people identify letters may lead to better understanding and therapy for dyslexia. Learning more about the human vision may help our society by creating new technology to help the blind drive and play baseball.

ACKNOWLEDGEMGMENTS

I want to thank Professor Denis Pelli for his excellent guidance and assistance in my research project. In addition, I want to thank Melanie Palomares for her constant support and great knowledge, which helped me a great deal in completing my project. Lastly, I want to thank Ms. Marianna L. Reep for her help in suggesting this Science Talent Search Report to me, and preparing me so well for it.

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