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Image Analysis Using Gabor Transforms: Correlated with Human Saccadic Movement Data to Identify the Human Visual Search Strategy

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THESIS

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Ralph J. St. John

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Abstract

The purpose of this thesis was to determine the relationship, if indeed any relationship exists, between the Gabor Correlation Coefficient (GCC) magnitudes of fixation points for a set of images which were viewed by six subjects and the human visual search strategy. A couple of different relationships were investigated. First, the data were analyzed to determine if the GCC magnitudes of human fixation points predicted the time ordered sequence of human fixation points during the performance of a visual search. Second, the data were analyzed to determine if there was a significant difference between the GCC magnitudes of the human fixation points and the GCC magnitudes of a random set of fixation points. Finally, the data were analyzed to ascertain whether there was a difference between the GCC magnitudes of the fixation points at the beginning of the visual search and the GCC magnitudes of the fixation points at the end of the visual search.

The results of this thesis indicated that the GCC magnitudes of the fixation points can not be used to predict the time ordered sequence of fixation points, however, a significant difference exists between the GCC magnitudes of the subject fixation points and the GCC magnitudes of the random set of fixation points. The data for this thesis did not indicate that the GCC magnitudes of the fixation points at the beginning of the visual search are greater than the GCC magnitudes of the fixation points at the end of the visual search.

From these results, a case can be made for the use of Gabor filters to predict the location of the features of interest within an image and, therefore, the Gabor filter could be used to perform a preliminary search of an image to determine if additional image processing is required or it could be used to model the human visual search strategy for a computer-based visual search.

IMAGE ANALYSIS USING GABOR TRANSFORMS: CORRELATED WITH HUMAN SACCADIC MOVEMENT DATA TO IDENTIFY THE HUMAN VISUAL SEARCH STRATEGY

I. *Introduction*

1.1 *Background*

1.1.1 *Human Visual System*. The human visual system is an image processing system which is capable of interrogating a complex image, display, or scene and, according to Kabrisky, acquire significant portions of complex images in times as short as two msec (10:129). However, the typical human visual search lasts several hundred milliseconds, depending on the complexity of the image and the information to be gleaned from the image. How the human searcher goes about interrogating the image is referred to as the search strategy.

In order to understand how the human visual system searches an image, one should first become familiar with the anatomy and physiology of the human visual system. The anatomy and the physiology of the human visual system can influence the search task to be performed. The components of the human visual system which are involved in the visual search are: the eye, the optic pathway, the striate or visual cortex, the posterior parietal cortex, and the superior colliculus.

1.1.1.1 *The Eye*. The human eye is a very complex and sensitive sensory organ which consists of three primary parts, the lens, the retina, and the muscles which are responsible for moving the eye. The lens with its adjustable aperture, called the iris, focuses the image on the retina. The retina is a multilayered light sensitive membrane which lines the interior wall of the eye. The retina consists of two sets of specialized light detection cells, called rods and cones. The rods and cones are structures which are sensitive to light. The rods are sensitive to all wavelengths of light in the visible range, while three families of cones are sensitive to the red, green, and blue wavelengths of light respectively. The rods and cones convert the light signals to electrical signals through a photochemical process. There are approximately 120 million rods and 6 million cones in the retina of the human eye. The cones are concentrated in the center of the field of view of the retina. The center of the field of view of the retina is referred to as the fovea. (2:3-4) The fovea "analyses a pattern of light on a much finer scale than the periphery of the retina can" (18:124). See Figure 1.

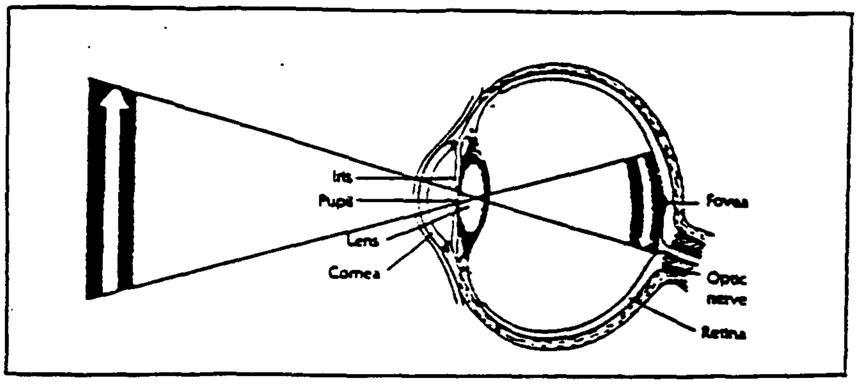

Figure 1. The Human Eye. (2:5)

1.1.1.2 *The Optic Pathway*. The optic pathway consists primarily of the optic nerve which takes the electrical signals generated in the retina and transmits them to the lateral geniculate body (LGB) and the superior colliculus. In mammals, prior to reaching the LGB and the superior colliculus, the electric signal passes through a special structure of the optic nerve referred to as the optic chiasm. The optic chiasm takes the signal from the left side of the retina in each eye and sends it to the left side of the brain and takes the signal from the right side of the retina in each eye and sends it to the right side of the brain. See Figure 2. Thus the visual field is split vertically through the center of the fovea with the left side mapped on the right visual area of the brain and the right side of the visual field mapped to the left side of the brain. These two half fields are fused so precisely that the animal is totally unaware of this seemingly eccentric visual hardware. Needless to say, damage to the system after the chiasm produces blindness in identical regions of both eyes; most humans have a hard time understanding this until the chiasm process is made clear to them. (8)

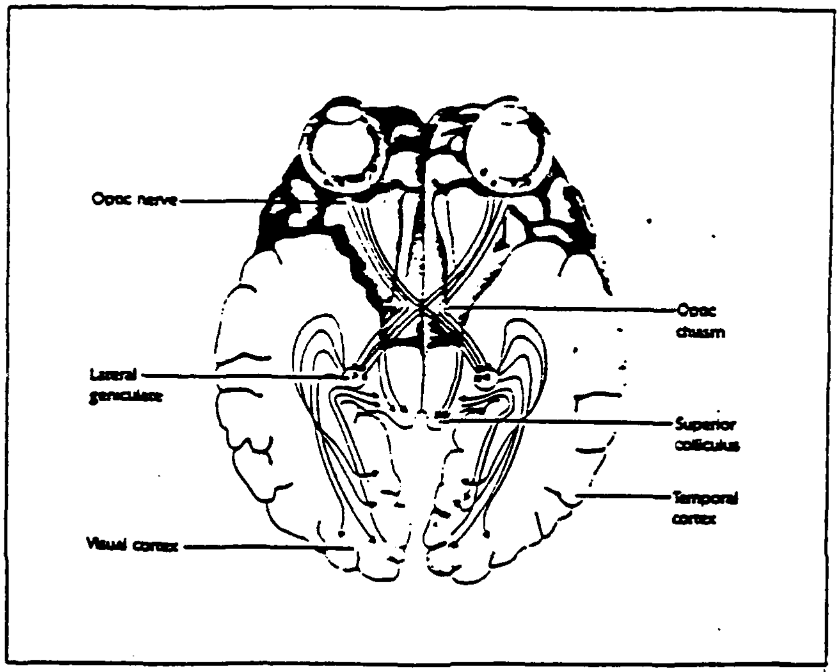

Figure 2. The Optic Pathway. (2:7)

1.1.1.3 *The Superior Colliculus.* The superior colliculus is located towards the rear of the midbrain section of the brain. See Figure 3. The superior colliculus responds to visual stimulation and directs visual attention to the stimulation. Experiments on primates by Wurtz indicate that cells within the superior colliculus respond to more than just visual stimulation. The superior colliculus also responds to auditory stimulation. Wurtz's experiments also suggest that "the response of the cells of the superior colliculus is consistent with the initiation of eye movement." (3:72) See Figure 3.

1.1.1.4 *The Striate Cortex.* The lateral geniculate body is "a collection of nerve cells whose axons extend into the striate cortex " (18:126). The striate cortex is "the rearmost part of the cerebral cortex. Here the cortex begins the analysis of the visual world for color, shape, motion and depth" (18:126). See Figure 3.

1.1.1.5 *The Posterior Parietal Cortex.* The posterior parietal cortex is located at the top of the brain and responds selectively to stimulants in the receptive fields of the cells of the posterior parietal cortex. The responses of these cells are observed whether or not the response to the stimuli is accompanied by eye movements. This indicates that the posterior parietal cortex is involved in the attention pathway prior to the movement of the eyes, rather than a response dependent on the actual movement of the eyes. (3:74) See Figure 3.

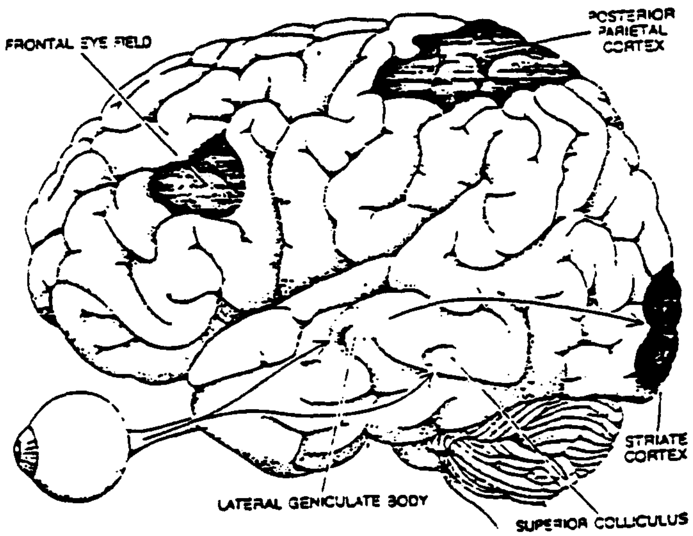

Figure 3. The Human Brain. (17:126)

1.1.2 *Visual Search.* The visual search, according to Robinson, is "defined as the coordinated temporal sequence of eye and head movements beginning with the signal to refixate a new target and ending with a response to the discrimination of that target" (15:691). In general, the visual search is conducted in two stages, "people first make a preliminary, global analysis of a display and only then guide their subsequent analysis" (14:275). Or put another way, "It seems that people may sometimes be able to recognize the overall "meaning" or "semantic context" of displays and scenes before they resolve all details within them. They may use this rapid recognition of the "meaning" of a display, or of a pattern of regular relationships within it, to guide their further interrogation of its component features" (14:277).

> The human, according to Rabbitt, "can recognize and adopt optimal search strategies. Evidently a person must have a repertoire of different search strategies, each of them optimal for a specific situation. In order to succeed one must first recognize the kind of display or scenario being looked at and then, very rapidly, access an appropriate search strategy from long-term memory (LTM) and deploy it as required" (14:274).

In order to more fully understand the visual search, one must examine the psychological and physiological factors, discussed earlier in Section 1.1.1, of the human which form the basis of the human visual search strategy.

The psychological factors are the factors of the visual search task which can be attributed to the human. Factors such as "the nature of the search task, the information the observer has about the target's characteristics, the observer's expectancies, and the observer's past experience" (5:145) influence the observer's eye movements during the search.

1.1.2.1 *Search Task.* The movement of the eyes is influenced by the actual search task being performed. Enoch (1969) found that observer's searching maps had eye movements which tended to fixate about the center of the maps. While, White and Ford (1960) observed that subjects fixate midway along scan lines on radar scopes. (6:148)

1.1.2.2 *Information.* The information the observer has about the target's characteristics will influence how the observer performs the visual search task. For example, if the observer knows the target can be discriminated by color, then the observer will use color as his primary discriminator in conducting the search (3:80). In fact, the observer can mentally prepare his search strategy prior to starting the actual search task.

1.1.2.3 *Expectancies.* The observer analyzes images based on the information the observer expects to glean from the image (6:150). Luria (1966) reported this after having recorded the eye movements of individuals who received differnt instructions as to how to analyze a picture. The individuals' search strategy differed according to the information they were required to ascertain by the question asked prior to searching the picture. See Figure 4. Scan pattern 1 was free observation. Scan pattern 2 was a response to the question "Tell me, is the family poor or wealthy?" Scan pattern 3 was in response to the question "How old are the people in the picture.?" Scan pattern 4 was in response to the question "What were they doing before the man entered the room?" Scan pattern 5 was a response to the instruction to "Try to memorize the clothing the people are wearing. Scan pattern 6 was a response to the instruction "Try to memorize the placement of the furniture." Scan pattern 7 was in response to the question "How long had the man been away from his family?" (11:273-275)

1.1.2.4 *Experience.* The experience of an individual affects the number of fixations required to find a target. This experience relates to both the searchers personal experience with the media to be searched and the searchers familiarity with the experimental procedures. According to Schaffer and Gould, observers who had previously participated in the visual search experiments required 50% fewer fixations than observers who had not participated in similar search experiments (6:150).

1.1.3 *Wavelet.* The wavelet is a function which is confined to a localized area. The typical wavelet is comprised of two components: the modulation component and the limiting component. The modulation component is a periodic function such as a sine wave or a square wave. The limiting component or envelope can be represented by a single period of a square wave, a Gaussian window, or and exponential function. (3:31)

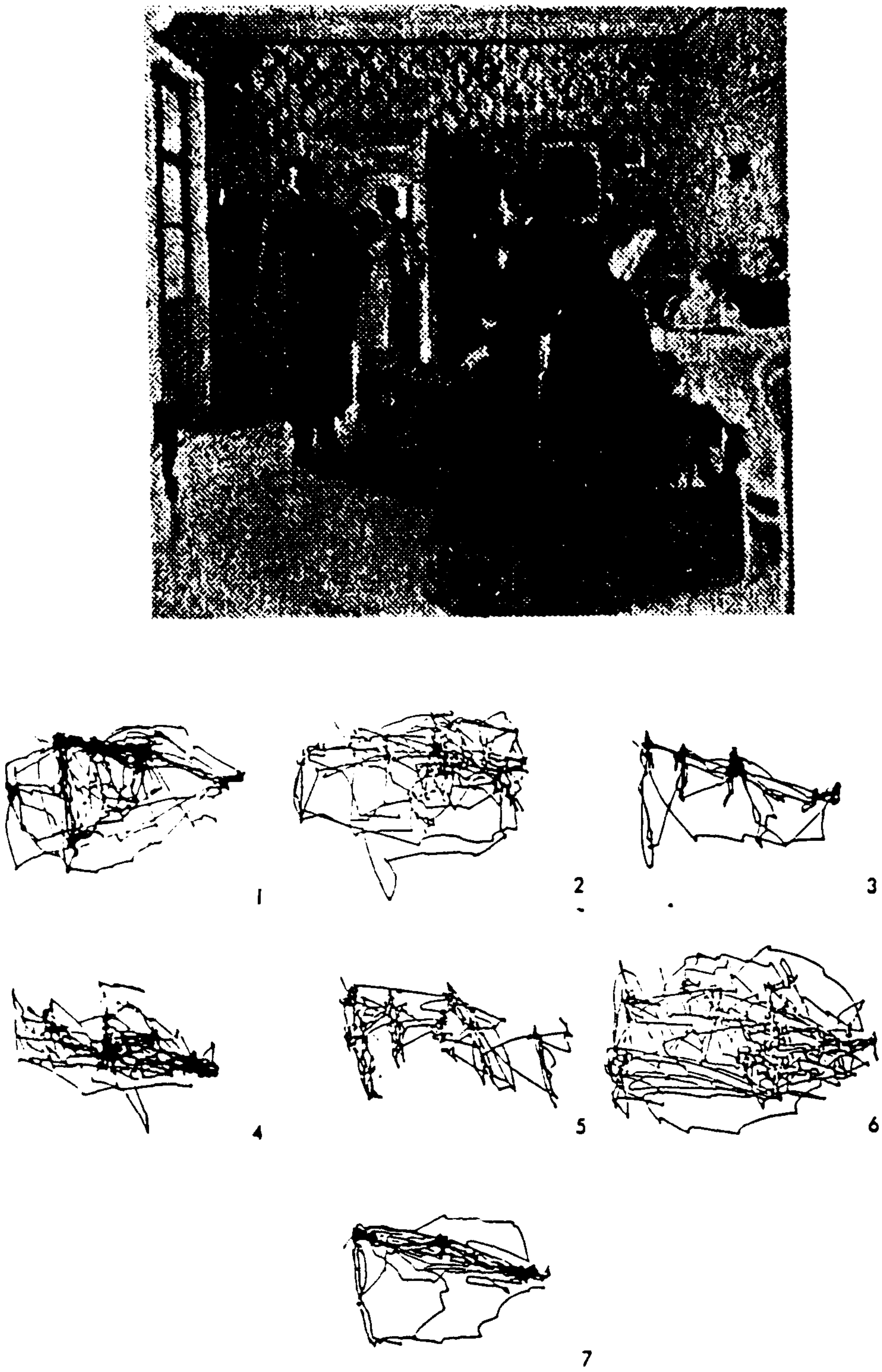

Figure 4. Varied Search Strategy, Dependent on Instructions to Searcher. (11:274)

The wavelet is a function which can be modified to more closely approximate the signal it is modelling. This modification can be performed in two ways. First, the modulation component can be modified by manipulating its period or phase. Second, the envelope can be modified by adjusting its size or shape. (3:33)

1.1.4 *Gabor Wavelets.* The Gabor wavelet is a general form of the Morlet wavelet. The Morlet wavelet is a set of orthogonal wavelets which have a sinusoidal modulation component and a Gaussian window as a limiting or envelope component. The envelope size is normally twice the period of the sinusoidal function and is modified by an exponential function. The Gabor wavelet equation is:

$$\Gamma(x,y) = e^{-.5\left(\frac{x^2+y^2}{\alpha^2+\beta^2}\right)} \sin[-2\pi(U_\phi x + V_\phi y) - \Psi] \tag{1}$$

The Gabor wavelet does in general form an orthogonal set of functions. (3:35) Figure 5 shows examples of Gabor wavelets.

In 1946, Dennis Gabor first presented the use of what is today referred to as the Gabor wavelet. Gabor indicated that a requirement existed to be able to represent signals simultaneously in both the time and frequency domains. These first applications were one-dimensional transforms. Gabor suggested the Gabor wavelet could be used to represent signals in communication and speech recognition applications. Gabor proposed the use of a sinusoidal signal multiplied by a Gaussian window. (4)

Even though Gabor first proposed the use of Gabor wavelets as a way to represent signals for communication and speech recognition applications, recent research has emerged in applying Gabor wavelets in image processing. The Gabor wavelet was expanded by Daugman into a two-dimensional space for the specific purpose of image processing. (1)

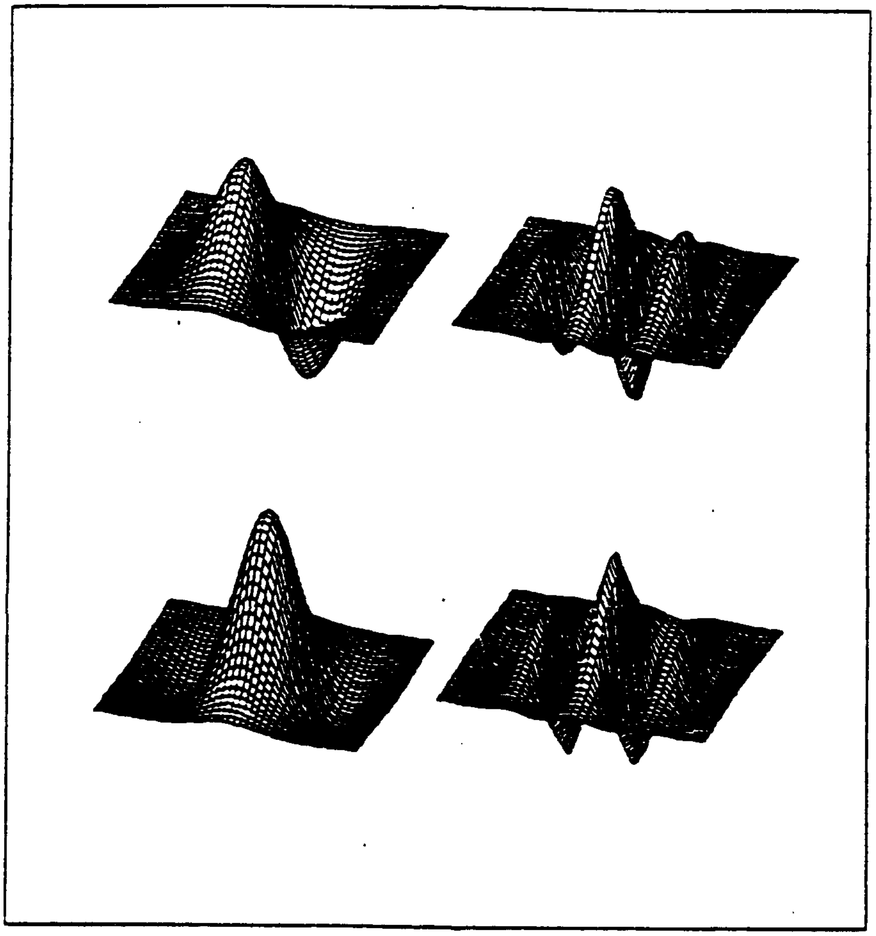

Figure 5. Examples of Two-dimensional Gabor Wavelets

1.2 *Problem Statement*

The ability of computer-based systems to rapidly and efficiently scan images, scenes, electronic components, as well as other objects of interest could be greatly enhanced if the search strategy of this system could be modelled after the premier image processing system, i.e. the human visual system.

1.3 *Research Objectives*

This thesis had two main objectives. First, image processing using Gabor transforms was performed and then correlated with human fixation points, recorded during a viewing experiment. The correlation was performed to determine if any relation exists between the peak values of Gabor Correlation Coefficients (GCCs) and the time ordered sequence of the eye fixation points. In other words, are the peak values of the GCC higher for the subject fixation points at the beginning of the image search than they are at the end of the image search?

Second, identify, if possible, the human visual search strategy (assuming that the Gabor transform is the basic attention mechanism for the human visual system) by using the data available about the search task performed during Fretheim's experiment. Fretheim's experiment is described in Section 1.7 of this thesis. Can the human visual search strategy be identified based on the peak values of the GCC of the Gabor transformed images and the psychological factors associated with the search task conducted during the Captain Fretheim's experiment?

1.4 *Definitions*

The following definitions should be helpful to the reader of this thesis.

1.4.1 *Saccade*. The movement of the eye between fixation points is referred to as a saccade. Saccade comes from a French word, saccader, meaning to jerk. The average saccade or movement between fixation points lasts 50 msec (18:124).

1.4.2 *Priming*. Priming is offering a word or image to the subject prior to the performance of the actual visual search task (17:2).

1.4.3 *Visual Attention*. Visual attention, according to Wurtz, is "the process of selecting important objects in the visual world" to concentrate on at the expense of other objects in the same visual world (18:124).

1.4.4 *Gabor Correlation Coefficient*. The Gabor Correlation Coefficient (GCC) is a measure of how well a Gabor transformation approximates the signal of a feature within an image. The GCC is a value between -1 and 1.

1.5 *Limitations*

The analysis for this thesis was based on the eye fixation point data collected by Erik Fretheim, during his Phd research at the Air Force Institute of Techology (AFIT) (3). The images used to collect this data used a 256 level grey scale monochrome format. Therefore, this thesis does not include the modelling of color with Gabor filters in identifying the human visual search strategy.

Also, all images used during the experimentation to collect the data were static. Therefore, the modelling of motion with Gabor filters in identifying the human visual search strategy was not considered in this thesis.

1.6 *Summary of Previous Research*

1.6.1 *Gabor Transform.* The Gabor transform is a set of transforms which have been used successfully by several researchers to model images or functions of the brain. The Gabor transform is comprised of two components: the modulation component and the limiting component. The modulation component is nothing more than a periodic function, such as a sine wave or a square wave. The limiting component is like a Gaussian window and merely limits the modulation component about a point. (1) See Figure 5.

1.6.2 *Visual Cortex.* Experiments, in the 1980s, performed by Jones and Palmer recorded the spatial response of the receptive field of simple cells in the visual cortex of the cat. Jones and Palmer showed how Gabor transforms could be used to model the image processing performed by the visual (striate) cortex of the cat. Jones and Palmer performed additional statistical measures consisting of least-mean-squared-errors and found that in 33 of 36 spatial responses and 34 of 36 spectral responses there was no statistically significant error in assuming a Gabor model for the actual physiological function. (1:1164-1165).

1.6.3 *VLSI Images.* In 1990, Mueller, while performiog research on his thesis at AFIT, used Gabor filters as a segmentation tool to discriminate the features of VLSI images. Specifically, Mueller used Gabor Transforms to locate the contacts of VLSI images (11:90).

1.7 *Summary of Fretheim's Research*

The impetus for this thesis was based on the results of the dissertation of Erik Fretheim and therefore the remainder of the summary of recent related research is based on his work. In chapter 3 of Fretheim's dissertation, he discusses the "Mechanism for a Vision Model." Based on the assumption that the human visual system uses, at least partly, the Gabor wavelet as an image analysis mechanism. In chapter three, Freitheim discusses the modelling of the visual cortex, by various researchers, using Gabor wavelets. Specifically, in Section 3.2, he indicates that by modelling the visual cortex with Gabor wavelets, the human perceptual responses to to certain experimental psychological phenomena, optical illusions, can be duplicated.(3) Richard A. Oberndorf, class GE-90D, also analyzed visual allusions using Gabor filters, AFIT thesis number AFIT/GE/ENG/90D-47. Although the optical illusion results are interesting, Fretheim's results which indicated that the Gabor transform can be used to model the base attention mechanism of the human visual system were investigated for this thesis.

The ability of most animals, not just man, to survive is rooted in their ability to adjust to their environment. For many species, their ability to adjust to a dynamic environment depends on their visual systems. For example, the horseshoe crab depends on its visual system for finding a mate and sensing danger (16:30). While humans, on the other hand, rely on their visual system for a multitude of uses, everything from reading facial expressions, in order to determine a person's intentions, to finding a mate. See Figure 6 for typical eye movement profile of person scanning a face.

As a matter of fact, Fretheim showed that Gabor filters can be modified and then used to highlight facial features. Additionally, Gabor filters can be used to model features with high contrasts and sharp contours, features humans tend to focus on and respond to. Fretheim concludes that "Gabor filters as an attentional mechanism meet an important biological test" (16:35). In order to perform the required analysis for this thesis, a complete understanding of the experiment conducted to gather the data is required. Therefore, the experimental design, setup, and procedures as well as the results of the subsequent data analysis are presented.

1.7.1 *Experimental Design*. Fretheim proposes the Gabor filter as a base attentional indicator for the human visual system. To this end, Fretheim designed an experiment to test his theory. The experiment was designed to collect the eye fixation points of human subjects during the performance of a visual search task. The images used for the experiment consisted of natural scenes and videomicrographs of VLSI circuits. According to Fretheim, the use of natural scenes and VLSI circuits for the experimental images was to force the subjects to focus on the objects in order to perform a legitimate search.

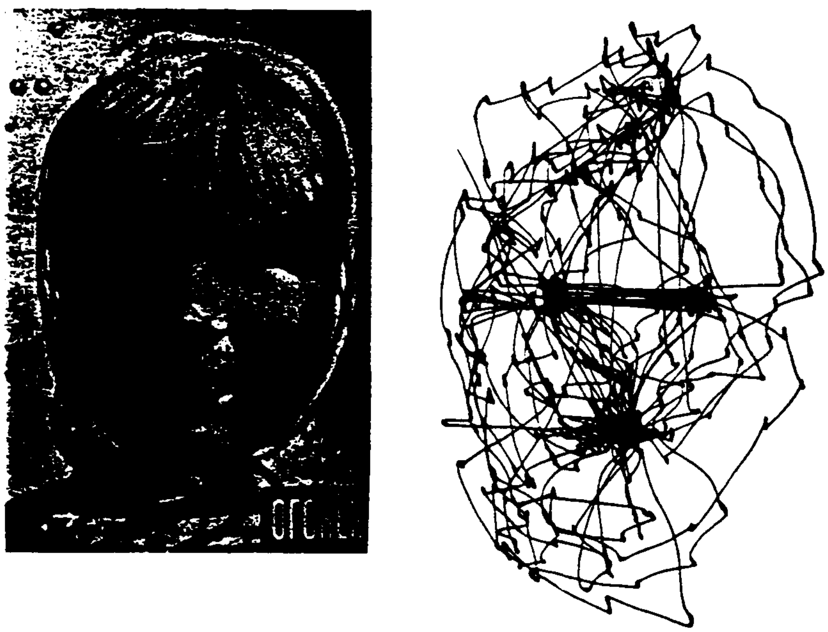

Figure 6. Typical Facial Eye Scan Pattern. (11:135)

Additionally, the images were colored only in 256 grey scale levels. Grey scale was used to avoid the confounding effect that would have resulted from the use of color to discriminate features in the images rather than the contours, edges, and areas of high contrast. The subjects were shown a variety of images. Each image was prefaced with a verbal cue, see Appendix B for the verbal cues, prior to being presented to the subject. The priming was used to force the subject to modify his search strategy. Data consisting of the subject's eye movements and scan patterns were collected for later analysis.

1.7.2 *Experimental Setup.* The eye movement data for Fretheim's experiment was collected at the Helmet Mounted Oculometer Facility (HMOF) of the Armstrong Aerospace Medical Research Laboratory (AAMRL). The HMOF is capable of displaying images for human experimentation, ascertaining the eye gaze angle of subjects, and calculating subject eye fixation as subjects searched images.

The HMOF samples eye location of the subject every 1/60th of a second. The HMOF is capable of displaying an entire image within one frame time. The HMOF presented the images via a 256 level grey scale format.

The HMOF is equipped with an audio system. The audio system facilitated the communication between the subject and the experimenter.

1.7.3 *Experimental Procedures.* The subjects for the experiment were AFIT students currently enrolled in the VLSI sequence of the AFIT School of Engineering. The subjects were selected, at least partly, on the basis of their familiarity with VLSI circuits. The subjects were also screened for normal vision.

The HMOF is calibrated according to the specific physical requirements of each subject. Each subject was then shown a set of 50 images on which to respond. The images were presented in a random order and preceded by a verbal cue (some images had more than one verbal cue) from the experimenter. The scan of each image was terminated by a response from the subject. After each image was scanned, a single fixation point was placed on the screen prior to the display of the next image.

1.7.4 *Data Analysis.* After the eye movement data traces were recorded, Fretheim determined the fixation points for each of the images for each of the subjects. For a comprehensive explanation of the process of picking fixation points, refer to Fretheim's dissertation.

Fretheim then checked the fixation points to determine if there was a high correlation between the fixation points and the Gabor filters. Each fixation point was correlated against a set of 378 Gabor filters. The maximum value of the GCC or the first GCC value greater than 0.5

were recorded. The parameters associated with these GCC magnitudes were also recorded. The maximum GCC magnitudes were saved for comparison with the GCC magnitudes for a set of random fixation points.

In order to provide a null hypothesis on which to make a comparison, a set of 100 random points from each image was selected for correlation. The random set of points was correlated with a set of 378 Gabor filters. Again, the maximum values of the GCC for the random fixation points were recorded after the correlation was complete. This set of GCC magnitudes for the random points forms the basis set for the null hypothesis.

> According to Fretheim, the "null hypothesis is established to test whether the mean of the maximum of the Gabor correlations of the population of random points is less than the mean of the maximum Gabor correlations of the population of fixation points" (3:93).

The results of the T-test are: "In 89% of the samples, the null hypothesis was rejected for a 95% confidence interval" (3:93). By rejecting the null hypothesis, the alternate hypothesis was accepted, that is, the average of the GCC magnitudes of the Gabor filters for the subject fixation points is greater than average of the GCC magnitudes of the Gabor filters for the random points. According to Fretheim, "the increased correlation values for fixation points imply that Gabor functions can accurately model the basic attention for human vision" (3:93).

Some images resulted in the acceptance of the null hypothesis. These results can also be explained based on the premise that Gabor filters model the base attention mechanism of the human visual system. A comprehensive explanation of these results can be found in Fretheim's dissertation.

1.8 *Summary*

The human visual system is the premier image processing system for pattern recognition and target detection applications. Generally, the human visual system outperforms all computer vision systems when it comes to processing images in the visible light range. The human is able to outperform these computer vision systems due to its ability to dynamically adopt a visual search strategy based on the search task to be performed. The human, after briefly viewing an image, adopts a search strategy based on the information resident in the image, the information the searcher expects to glean from the image, the searcher's experience, or the nature of the search task. If the human visual search strategy could be identified and then modelled, the model would be of great value for incorporation into a computer vision system or a neural network vision system. The goal of this thesis was to identify the visual search strategy and facilitate the development of a human visual search strategy model.

II. Approach

2.1 *Motivation*

In 1989, Mueller showed that the Gabor transformation of VLSI images was effective in the segmentation of significant features within the VLSI images. Specifically, he was able to use Gabor filtering of VLSI images to reveal and locate the contacts within videomicrographs of VLSI circuits.

In 1991, during the performance of his research for his doctoral dissertation, Fretheim investigated the use of Gabor filters on a variety of images to model the base attentional mechanism for a proposed human visual system model. Fretheim, through experimentation, showed that the average of the GCC magnitudes for human subject fixation points on a wide variety of images was higher than the average of the GCC magnitudes for randomly selected points on the same images. From this experimentation, Fretheim concluded that the Gabor transformation could indeed model the base attentional mechanism for the human visual system model. Fretheim's research raised a couple of questions.

First, is there a definitive relationship between the strength of the GCC and the time ordered sequence of the fixation points of the human subjects? Second, can the human search strategy be modelled based on the magnitude of the GCC for the features contained within an image? Third, is there a well defined relationship between the strength of the GCC at the beginning and end of an image search or, said another way, are the magnitudes of the GCC at the beginning of the visual search greater than the magnitudes of the GCC at the end of the visual search? Last, if the answer to any of these questions is yes, how can the Gabor transform be used to develop a reliable model for the human visual system search strategy? The remainder of this chapter will deal with the approach to be employed to ascertain answers to all these questions and possibly formulate more questions and, hopefully, more answers.

2.2 *Gabor Search Hypotheses*

Prior to examining the approach to be employed to answer the above questions, it would be instructive to postulate what one would expect to see if indeed the Gabor transform does play a role in determining the time ordered sequence of fixations during the human visual search.

2.2.1 *Hypothesis One.* One hypothesis was that the GCC magnitudes for the human subject fixation points would be highest at the beginning of the visual search, the GCC magnitudes would then linearly decrease for the next couple fixation points, and at some point the magnitude of the GCC for the subsequent fixation points would alternate between high and low values, depending on the magnitude of the GCC corresponding to the features of interest within the image. These features of interest would be the features which provide the meaning or semantics of the image. A plot of this hypothesis would exhibit a relatively high GCC magnitude, followed by decreasing GCC magnitudes for several points, and ending with GCC magnitudes which alternate between high and low values. Figure 7 is a sample plot of GCC magnitudes for Hypothesis One.

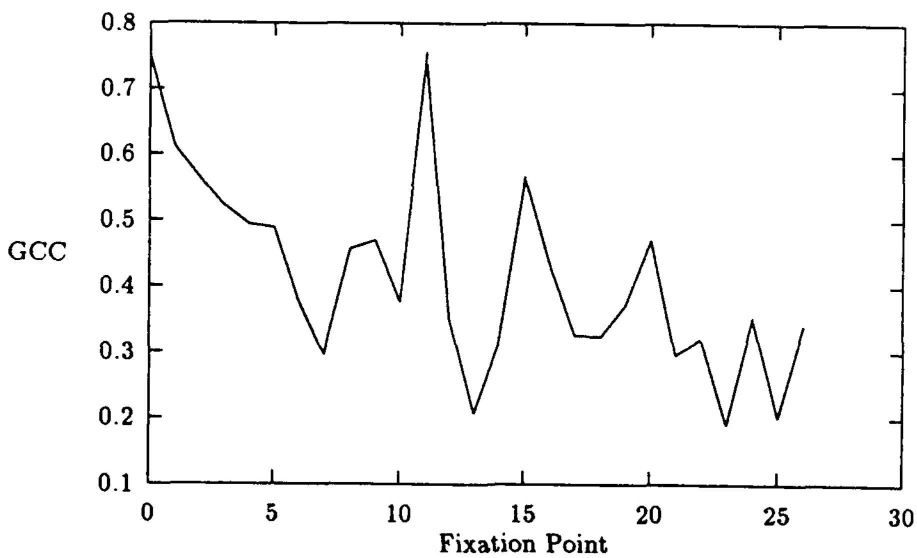

Figure 7. Sample Plot for Hypothesis One

2.2.2 *Hypothesis Two.* Another hypothesis was that the visual search strategy is formed after an initial scan of the image has been performed and information about the image is ascertained. The subsequent search would be driven by the relative strength of the GCC of the features within the image. In other words, the magnitude of the GCC for the first couple of fixation points could very well appear to be random in nature and then after the first few fixations the search strategy is driven by the magnitude of the GCC. As in the first hypothesis, the GCC magnitudes for the human subject fixation points would be highest at the beginning of the visual search, the GCC magnitudes would then linearly decrease for the next couple fixation points, and at some point the magnitude of the GCC for the subsequent fixation points would alternate between high and low values, depending on the magnitudes of the GCC corresponding to the features of interest within the image. Again, a couple of pictures may serve better to illustrate this hypothesis. Figures 8 and 9 illustrate two sample plots for Hypothesis Two.

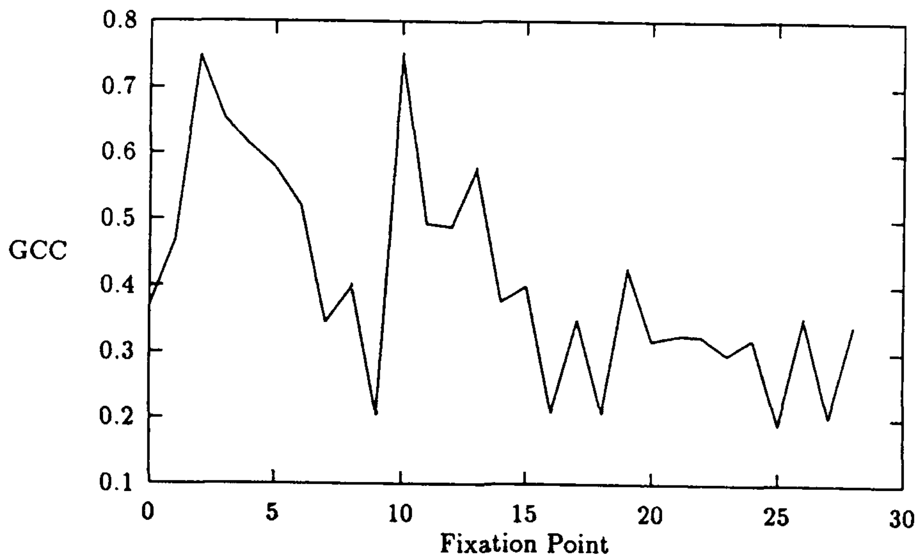

Figure 8. Sample Plot for Hypothesis Two

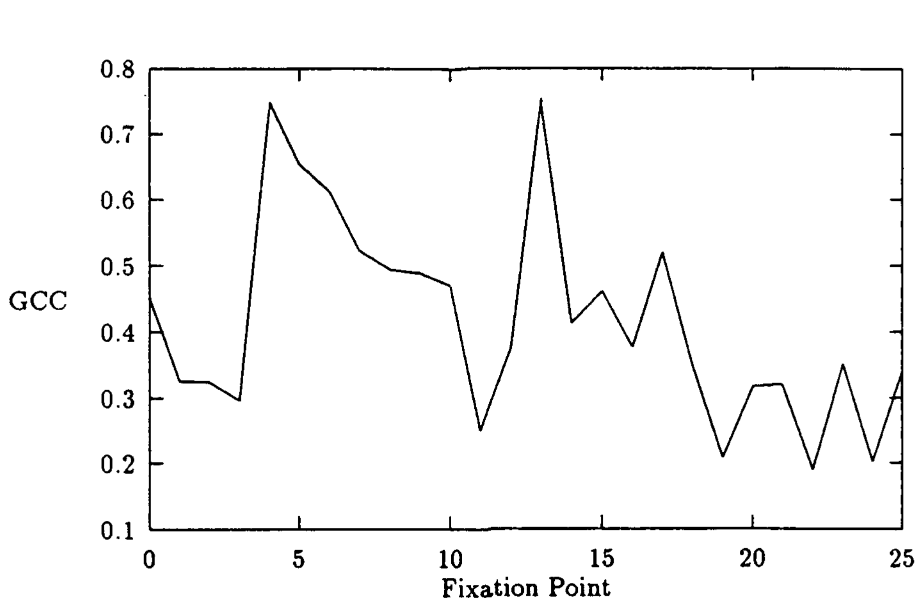

Figure 9. Sample Plot for Hypothesis Two

2.2.3 *Hypothesis Three.* A third hypothesis was that the strength of the GCC has no exclusive relationship with the time ordered sequence of fixation points during the human visual search. However, the majority (greater than 50%) of the GCC magnitudes of the subject fixation points are greater than the median of the GCC magnitudes of a random set of fixation points.

2.3 *Approach to Evaluate the Three Hypotheses*

The approach taken to evaluate each of the three hypotheses was to find the largest GCC value of each fixation point for all images for which subject data was available. The analysis software used by Fretheim to find the magnitude of the GCC was modified to find the maximum GCC magnitude for each subject fixation point. After the maximum value was found, the values for the GCC were plotted with respect to the time ordered sequence of fixation points. Additionally, the GCC values for each fixation point were then averaged across all six subjects and plotted. This process was used to test all three hypotheses. Additional processes for a specific hypothesis are detailed in the following sections.

2.3.1 *Approach One*. Approach one was performed to test Hypotheses One and Two. This first approach was to find the maximum value for the GCC for each fixation point within an image for each subject. The maximum value of the GCC for each fixation point within an image was plotted on an axis with the time ordered sequence of the fixation points on the horizontal axis and the magnitudes of the GCC on the vertical axis. The plot was then examined to determine if it resembled the plot of the first or second hypothesis.

Next, the maximum GCC magnitude for each fixation point was averaged across all six subjects. The average was then plotted on the same axis described above. The plot was then examined to determine it resembled the plot of the first or second hypothesis.

2.3.2 *Approach Two*. The plots of the magnitudes of the GCC versus the time ordered sequence of fixation points for each subject was compared to the plots of the magnitudes of the GCC of the Baseline set of fixation points to see if a significant difference between the two plots existed. Additionally, the distribution of the GCC magnitudes for the subject fixation points and the average were ascertained to see if the majority of the GCC magnitudes of the subject fixation points and the average were greater than the median of the GCC magnitudes of a random set of fixation points. The average of the magnitudes of the GCC for fixation points was plotted on the same plot as the magnitudes of the GCC of the Baseline set of fixation points to see if any significant difference between the two plots existed.

2.3.2.1 *Acceptance Criteria for Hypothesis Three*. The only criteria for the acceptance of Hypothesis Three is that percentage of the magnitudes of the GCC of the fixation points for the respective subjects and images above the median of the magnitudes of the GCC for the random fixation points must exceed 50%. The median of the GCC magnitudes for the random set of fixation points was chosen for comparison because plots of the images showed that the distribution of the GCC magnitudes was based, at least partially, on the amount of high contrast areas within the image.

2.4 *Randomness Test*

The plots for the individual subjects and the average of the magnitudes of the GCC across all subjects resembled the plots of the GCC magnitudes the random set of fixation points which formed the basis set for Fretheim's null hypothesis. Therefore, an additional analysis was performed to demonstrate the randomness or lack of randomness of the magnitudes of the GCC.

The additional analysis ascertained the distribution of the magnitudes of the GCC for the Baseline, the subjects, and the average of GCC magnitudes for each fixation point across all six subjects. If the subject and average across subjects were truly random, their distributions should have the same distribution as the distribution of the GCC magnitudes of the Baseline set of fixation points.

Also, the median value of the magnitudes of the GCC of the Baseline set of fixation points for the representative set of images was found. The percentage distribution of the GCC magnitudes for the six subjects and the average for each fixation point across all subjects was examined in an order to accept or reject the third hypothesis. The results of this additional analysis are presented in tabular form, Tables 1 - 14, in the next chapter.

2.5 *Data*

Initially, the processing and plotting was to be performed on all 50 images for all six subjects. After plotting the GCC magnitudes for 15 images for all six subjects, it became obvious that the data was repetitive and therefore a representative data set was chosen on which to produce a complete set of data for analysis. The plots of the magnitudes of the GCC of the subject fixation points for the representative data set are included in this thesis as an appendix, Appendix A. The representative set of images is described in the following paragraph.

The first image selected was an image of a human face, see Figure 10. The second image selected was an image of a natural scene, mountains and trees, see Figure 11. The third image was that of a nonsensical cartoon, a snake camouflaged on a sofa, requiring some complex manipulation by the subjects' visual processing system, see Figure 12. The fourth image was a military scene depicting two soldiers training a weapon on tanks crossing a bridge, see Figure 13. The last three images were videomicrographs of VLSI circuits, see Figures 14, 15, and 16. Three images of videomicrographs of VLSI circuits were chosen for complete analysis because of the background of the subjects used in Fretheim's experiment.

Figure 10. Anna Image

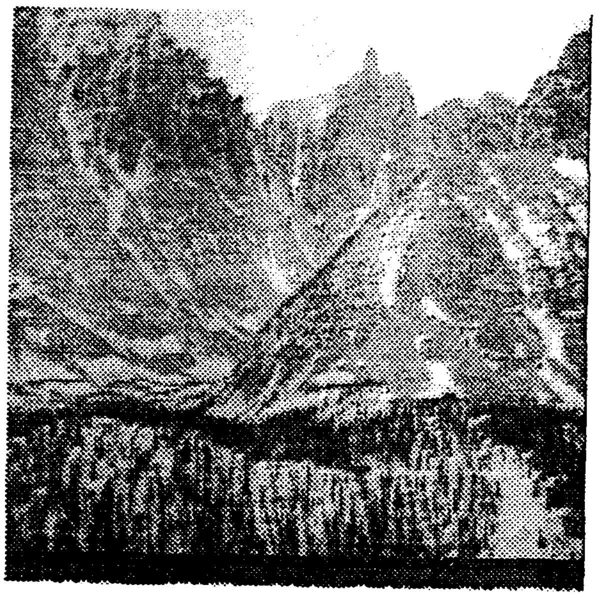

Figure 11. Mountain Image

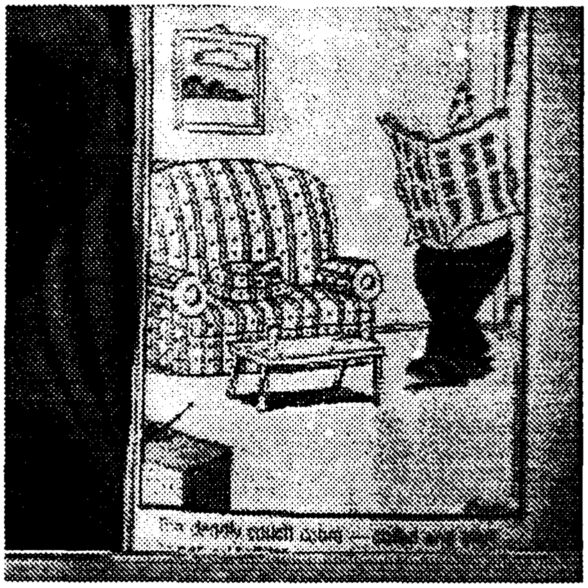

Figure 12. Cobra Image

Figure 13. New23 Image

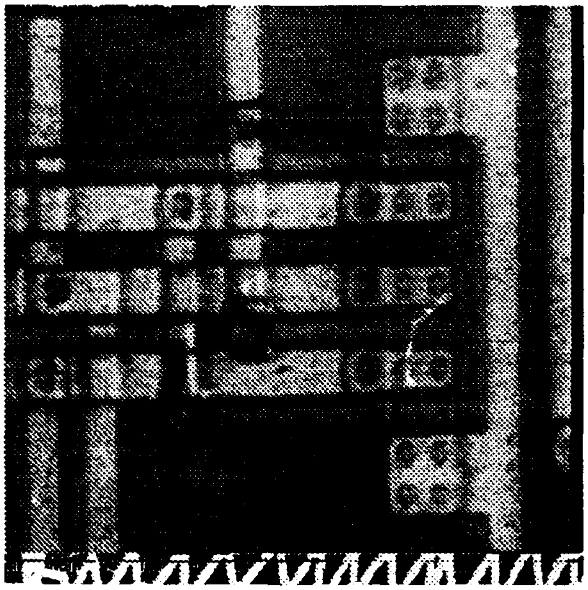

Figure 14. Chipc1 Image

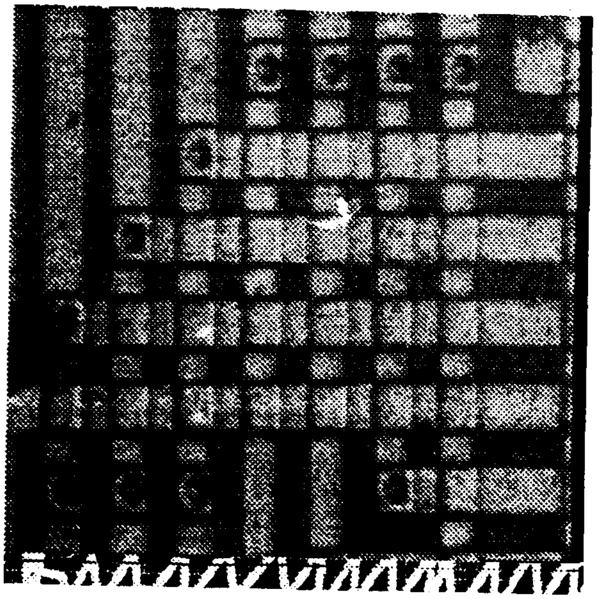

Figure 15. Chipc2 Image

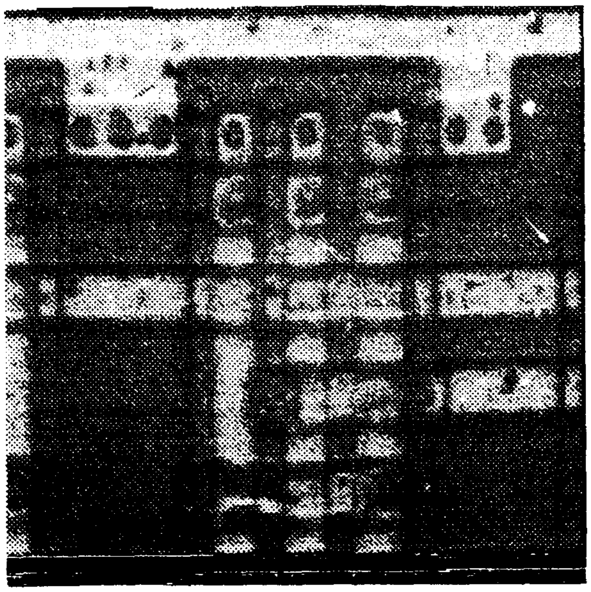

Figure 16. New7 Image

III. *Results*

3.1 *Plots*

The plots used to accept or reject Hypothesis One or Two are included in Appendix A. However, the plots which resemble the plots of Hypothesis One or Two are included here. The first plot, Figure 17, resembles Hypothesis One. The second and third plots, Figures 18 and 19, resemble Hypothesis Two. Figures 23 - 78, in Appendix A, are plots of the GCC magnitudes plotted against the time ordered sequence of fixation points for each of the subjects, the Average, and the Baseline set. The plots are presented by image in the following order: the Baseline, Subject A, Subject B, Subject I, Subject J, Subject K, Subject S, and the Average. The plots were examined to determine if they resembled the hypothetical plots of either Hypothesis One or Two. The examination results are summarized in Tables 15 - 21 in Section 3.3.

Additionally, the average of the GCC magnitudes for each fixation point across all subjects was plotted on the same graph as the Baseline set to ascertain if a significant difference between their GCC magnitudes existed, see Figures 79 - 85. The thin line plotted on the Average versus Baseline plot represents the plot of the Average and the thick line with the boxes represents the plot of the Baseline. From the plots it became obvious that a significant difference indeed existed.

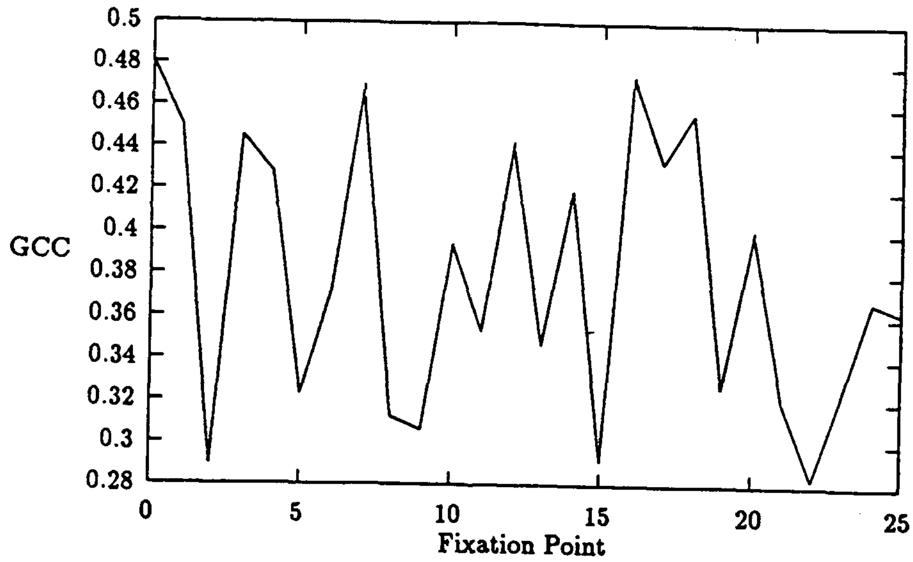

Figure 17. Plot of Subject B - Mountain Image

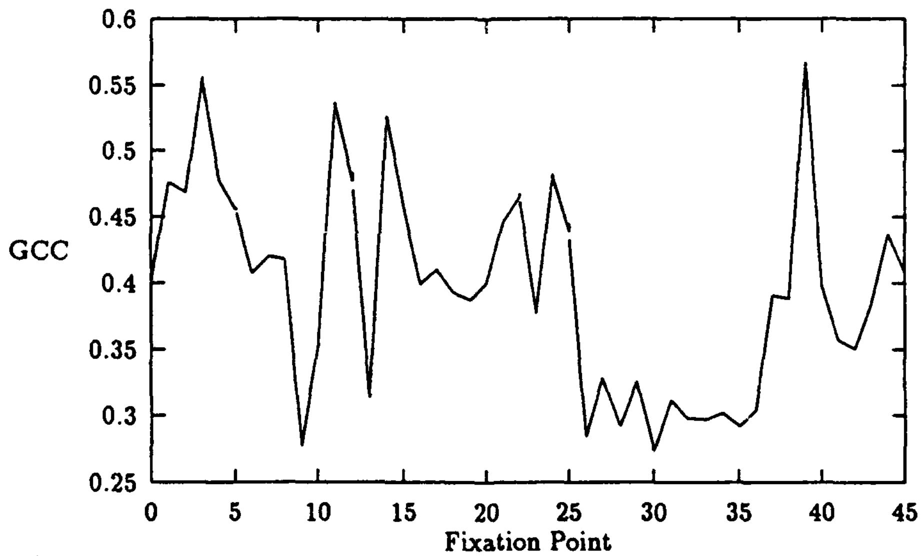

Figure 18. Plot of Subject J - Anna Image

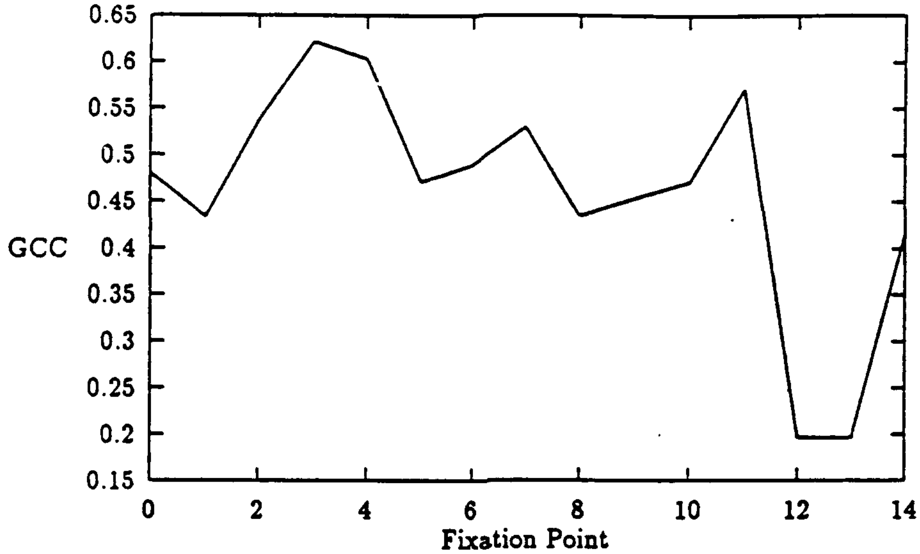

Figure 19. Plot of Subject I - Chipc2 Image

3.2 *Distribution Tables by Image*

The tables showing the distribution of the magnitudes of the GCC magnitudes for the Baseline, the six subjects, and the average of the GCC magnitudes for each fixation point across all subjects are presented in this section. Tables 1, 3, 5, 7, 9, 11, and 13 give the number of GCC magnitudes which are greater than the GCC value in the leftmost column. The GCC value in the leftmost column represent the typical range of GCC values for most images. The tables are presented for each image. Tables 2, 4, 6, 8, 10, 12, and 14 give the percentage of the GCC magnitudes greater than the GCC value in the leftmost column. Again, these tables are presented for each image. The primary usage of these tables is to test for randomness of GCC magnitudes for each subject and the Average. Also, a quick check of the row with the median value of the Baseline GCC magnitudes reveals whether the corresponding subject is accepted or rejected by the criteria for the third hypothesis.

For Tables 1, 3, 5, 7, 9, 11, and 13, column one is the GCC magnitude and columns 2 - 9 are the number of GCC magnitudes for the corresponding Baseline, Average, Subject A, Subject B, Subject I, Subject J, Subject K, and Subject S, respectively, which are greater than the GCC value in the first column. Row 11 is the total number of fixation points for the corresponding data set.

For Tables 2, 4, 6, 8, 10, 12, and 14, column one is the GCC magnitude and columns 2 - 9 are the percentage of GCC magnitudes for the corresponding Baseline, Average, Subject A, Subject B, Subject I, Subject J, Subject K, and Subject S, respectively, which are greater than the GCC value in the first column.

Table 1. Number of Fixation Points with GCC Value Greater - Anna Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	95	46	9	33	28	46	11	33
0.25	57	46	9	33	28	46	11	33
0.26	50	46	9	33	28	46	11	33
0.30	26	44	8	31	25	39	9	31
0.35	10	41	6	23	23	33	6	26
0.40	3	16	4	14	17	22	2	17
0.45	3	3	3	7	12	12	1	9
0.50	0	2	0	1	2	4	0	5
0.55	0	1	0	0	2	2	0	3
Total #F/P	100	46	9	33	28	46	11	33

Table 2. Percent of Fixation Points with GCC Value Greater - Anna Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	95.00	100	100	100	100	100	100	100
0.25	57.00	100	100	100	100	100	100	100
0.26	50.00	100	100	100	100	100	100	100
0.30	26.00	95.65	93.94	90.91	89.29	84.78	81.82	93.94
0.35	10.00	86.96	66.67	69.70	82.14	71.74	54.55	78.79
0.40	3.00	34.78	60.87	33.40	60.71	47.83	18.18	51.52
0.45	3.00	6.52	33.33	21.21	42.86	26.09	9.09	27.28
0.50	0	4.35	0	3.03	7.15	8.70	0	15.15
0.55	0	2.17	0	0	7.15	4.35	0	9.09

Table 3. Number of Fixation Points with GCC Value Greater - Mountain Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	95	56	36	26	31	56	13	51
0.25	61	56	36	26	31	55	13	51
0.26	50	56	36	26	30	55	12	50
0.30	27	55	32	23	30	49	12	46
0.35	15	43	22	16	21	39	10	33
0.40	6	14	11	11	19	18	4	11
0.45	3	0	2	5	11	5	1	4
0.50	0	0	1	0	1	1	0	0
0.55	0	0	0	0	0	0	0	0
Total #F/P	100	56	36	26	31	56	13	51

Table 4. Percent of Fixation Points with GCC Value Greater - Mountain Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	95.00	100	100	100	100	100	100	100
0.25	61.00	100	100	100	100	98.21	100	100
0.26	50.00	100	100	100	96.77	98.21	92.31	98.04
0.30	27.00	98.21	88.89	88.46	96.77	87.50	92.31	90.20
0.35	15.00	76.79	61.11	61.54	67.74	69.65	76.92	64.71
0.40	6.00	25.00	30.56	42.31	61.29	32.14	30.77	21.52
0.45	3.00	0	5.56	19.23	35.48	8.93	7.69	7.84
0.50	0	0	2.78	0	3.23	1.79	0	0
0.55	0	0	0	0	0	0	0	0

Table 5. Number of Fixation Points with GCC Value Greater - Cobra Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	97	34	14	30	29	28	12	34
0.25	76	34	14	30	29	27	12	34
0.30	53	34	13	30	28	23	12	32
0.31	50	34	13	30	28	22	12	32
0.35	33	32	11	26	25	18	11	30
0.40	23	23	7	18	18	11	7	21
0.45	17	5	4	12	12	6	5	13
0.50	5	0	0	5	3	0	2	3
0.55	0	0	0	1	2	0	0	0
Total #F/P	100	34	14	30	29	28	12	34

Table 6. Percent of Fixation Points with GCC Value Greater - Cobra Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	97.00	100	100	100	100	100	100	100
0.25	76.00	100	100	100	100	96.43	100	100
0.30	53.00	100	92.86	100	96.55	82.43	100	94.12
0.31	50.00	100	92.86	100	96.55	78.57	100	94.12
0.35	33.00	94.12	78.57	86.67	86.21	64.29	91.67	88.24
0.40	23.00	67.65	50.00	60.00	62.07	39.29	58.33	61.77
0.45	17.00	14.71	28.57	40.00	41.38	21.43	41.67	38.24
0.50	5.00	0	0	16.67	10.34	0	16.67	8.82
0.55	0	0	0	3.33	6.90	0	0	0

Table 7. Number of Fixation Points with GCC Value Greater - New23 Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	96	68	19	38	55	57	37	67
0.25	67	67	19	34	52	53	37	64
0.30	56	66	17	28	42	44	30	57
0.31	50	65	17	26	41	43	28	57
0.35	37	58	15	21	36	38	25	51
0.40	30	38	12	16	31	33	20	38
0.45	12	22	10	14	20	22	6	28
0.50	9	3	6	10	7	17	2	15
0.55	3	1	1	6	3	8	2	8
Total #F/P	100	68	19	38	55	59	38	68

Table 8. Percent of Fixation Points with GCC Value Greater - New23 Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	96.00	100	100	100	100	96.61	97.37	98.53
0.25	67.00	98.53	100	89.47	94.55	89.83	97.37	94.12
0.30	56.00	97.06	89.47	73.68	76.36	74.58	78.95	83.82
0.31	50.00	95.59	89.47	68.42	74.54	72.88	73.68	83.82
0.35	37.00	85.29	78.95	55.26	65.45	64.41	65.79	75.00
0.40	30.00	55.88	63.16	42.11	56.36	55.93	52.63	55.88
0.45	12.00	32.35	52.63	36.84	36.36	37.29	15.79	41.18
0.50	9.00	4.41	31.58	26.32	12.73	28.81	5.26	22.06
0.55	3.00	1.47	5.26	15.79	5.45	13.56	5.26	11.77

Table 9. Number of Fixation Points with GCC Value Greater - Chipc1 Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	92	55	21	36	50	53	19	31
0.25	78	55	20	36	46	52	18	29
0.30	59	55	20	33	45	49	18	26
0.33	50	55	20	32	44	49	17	24
0.35	46	53	20	32	41	49	17	24
0.40	33	49	18	31	33	45	17	19
0.45	17	34	13	26	22	36	10	13
0.50	5	9	7	18	12	22	6	7
0.55	2	2	5	12	9	10	1	4
Total #F/P	100	56	21	36	50	56	19	31

Table 10. Percent of Fixation Points with GCC Value Greater - Chipc1 Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	92.00	98.21	100	100	100	94.64	100	100
0.25	78.00	98.21	95.24	100	92.00	92.86	94.74	93.55
0.30	59.00	98.21	95.24	91.67	90.00	87.50	94.74	83.87
0.33	50.00	98.21	95.24	88.89	88.00	87.50	89.47	77.42
0.35	46.00	94.64	95.24	88.89	82.00	87.50	89.47	77.42
0.40	33.00	87.50	85.71	86.11	66.00	80.36	89.47	61.29
0.45	17.00	60.71	61.91	72.22	44.00	64.29	52.64	41.94
0.50	5.00	16.07	33.33	50.00	24.00	39.29	31.58	22.58
0.55	2.00	3.57	23.81	33.33	18.00	17.86	5.26	12.90

Table 11. Number of Fixation Points with GCC Value Greater - Chipc2 Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	98	64	45	13	13	64	19	17
0.25	97	64	44	13	13	64	19	14
0.30	85	64	43	13	13	62	19	14
0.35	66	61	40	10	13	59	19	14
0.375	50	55	40	9	13	56	19	14
0.40	36	52	38	7	13	52	17	12
0.45	18	34	31	5	10	37	8	7
0.50	6	14	17	2	5	16	1	5
0.55	0	4	6	0	3	10	0	3
Total #F/P	100	65	48	13	15	65	19	17

Table 12. Percent of Fixation Points with GCC Value Greater - Chipc2 Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	98.00	98.46	93.75	100	86.67	98.46	100	100
0.25	97.00	98.46	91.62	100	86.67	98.46	100	82.35
0.30	85.00	98.46	89.58	100	86.67	95.39	100	82.35
0.35	66.00	93.85	83.33	76.92	86.67	90.77	100	82.35
0.375	50.00	84.62	83.33	69.23	86.67	86.15	100	82.35
0.40	36.00	80.00	79.17	53.85	86.67	80.00	89.48	70.59
0.45	18.00	52.31	64.58	38.46	66.67	56.92	42.11	41.18
0.50	6.00	21.54	35.42	15.39	33.33	24.62	5.26	29.41
0.55	0	6.15	12.50	0	20.00	15.39	0	17.65

Table 13. Number of Fixation Points with GCC Value Greater - New7 Image

GCC Value	Base #F/P W/GCC Above	Avg #F/P W/GCC Above	A #F/P W/GCC Above	B #F/P W/GCC Above	I #F/P W/GCC Above	J #F/P W/GCC Above	K #F/P W/GCC Above	S #F/P W/GCC Above
0.20	91	32	19	9	29	31	7	11
0.25	80	32	18	9	28	30	6	8
0.30	67	32	18	9	28	30	4	6
0.35	50	32	18	8	28	27	4	2
0.40	25	27	16	8	25	23	3	2
0.45	9	23	15	7	22	20	3	1
0.50	0	10	13	7	16	14	2	1
0.55	0	3	8	3	7	5	0	0
Total #F/P	100	33	19	9	29	33	8	11

Table 14. Percent of Fixation Points with GCC Value Greater - New7 Image

GCC Value	Base %F/P W/GCC Above	Avg %F/P W/GCC Above	A %F/P W/GCC Above	B %F/P W/GCC Above	I %F/P W/GCC Above	J %F/P W/GCC Above	K %F/P W/GCC Above	S %F/P W/GCC Above
0.20	91.00	96.97	100	100	100	93.94	87.50	100
0.25	80.00	96.97	94.74	100	96.55	90.91	75.00	72.73
0.30	67.00	96.97	94.74	100	96.55	90.91	50.00	54.55
0.35	50.00	96.97	94.74	88.89	93.10	81.82	50.00	18.18
0.40	25.00	81.82	84.21	88.89	86.21	69.70	37.50	18.18
0.45	9.00	69.70	73.95	77.78	75.86	60.61	37.50	9.09
0.50	0	30.30	68.42	77.78	55.17	42.42	25.00	9.09
0.55	0	9.09	42.11	33.33	24.14	15.15	0	0

3.3 *Results Tables by Image*

The following tables summarize the results of the interpretation of the plots in Appendix A and the tables in Section 3.2. The tables summarize the results by image. The first column identifies the Baseline, the subject, and the average across all subjects. The average across all subjects is the average of the GCC magnitudes for each fixation point across all six subjects. Column two gives the number of fixation points for the Baseline, the subjects, and the Average. The third column gives the median value for the plot of the Baseline, the subject, and the Average. The fourth and fifth columns give the low and high GCC magnitudes for the Baseline, the subjects, and the Average. For the Average, the asterisk low and high GCC magnitudes are the GCC magnitudes obtained by averaging across at least two subjects. In other words, lower and higher GCC magnitudes were observed in the plot, however, these lower and higher values were observed at the end of the plot and therefore only reflect the low and high GCC magnitudes of the subject with the most fixation points. For example, the plot of the Average for Anna image exhibited a low GCC magnitude of 0.30 and a high GCC magnitude of 0.57, however, these GCC magnitudes were not average GCC magnitudes, rather they were GCC magnitudes of Subject J only. Therefore, the low GCC magnitude for this plot is 0.32 and the high GCC magnitude for this plot is 0.50. The low GCC magnitude is an average across four subjects and the high GCC magnitude is an average across five subjects. Column six gives the percentage of the GCC magnitudes above the median of the Baseline plot. For example, for the Anna image, all six subjects as well as the Average have 100% of their GCC magnitudes above the median GCC magnitude of the Baseline. Columns seven and eight summarize the results of the inspection of the plots of GCC magnitudes versus the time ordered sequence of fixation points for acceptance of Hypotheses One and Two, based on the criteria in Sections 2.3.1.1 and 2.3.1.2. Column nine summarizes the results of the inspection of the tables in Section 3.2 for acceptance of Hypothesis Three, based on the criteria in Section 2.3.2.1.

At this time a brief synopsis of the results from these tables is presented by image. The Baseline plots for all images did not resemble the plots for Hypotheses One and Two. Also, Hypothesis Three was not applicable to the Baseline set of GCC magnitudes for fixation points.

3.3.1 *Anna Image*. One subject's plot, Subject S, resembles Hypothesis One. One of the subject's plots, Subject J, resembles Hypothesis Two. Additionally, all six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. See Table 15.

Table 15. Results for Anna Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp 1	Hyp 2	Hyp3
Base	100	0.26	0.13	0.47	-	No	No	NA
A	9	0.37	0.26	0.47	100	No	No	Yes
B	33	0.375	0.29	0.54	100	No	No	Yes
I	28	0.425	0.28	0.57	100	No	No	Yes
J	46	0.375	0.27	0.57	100	No	Yes	Yes
K	11	0.36	0.29	0.46	100	No	No	Yes
S	33	0.425	0.26	0.56	100	Yes	No	Yes
Avg	46	0.39	0.32*	0.50*	100	No	No	Yes

3.3.2 *Mountain Image*. One subject's plot, Subject B, resembles Hypothesis One. Additionally, all six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. See Table 16.

3.3.3 *Cobra Image*. None of the subjects' plots resemble Hypothesis One or Two. Additionally, all six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. See Table 17.

3.3.4 *New23 Image*. None of the subjects' plots resemble Hypothesis One or Two. Additionally, all six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. See Table 18.

Table 16. Results for Mountain Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp 1	Hyp 2	Hyp3
Base	100	0.26	0.12	0.49	-	No	No	NA
A	36	0.36	0.28	0.51	100	No	No	Yes
B	26	0.37	0.28	0.48	100	Yes	No	Yes
I	31	0.45	0.25	0.51	96.77	No	No	Yes
J	56	0.375	0.25	0.51	98.21	No	No	Yes
K	13	0.39	0.26	0.47	92.31	No	No	Yes
S	51	0.37	0.26	0.47	98.04	No	No	Yes
Avg	56	0.37	0.31*	0.44*	100	No	No	Yes

Table 17. Results for Cobra Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp1	Hyp2	Hyp3
Base	100	0.31	0.18	0.53	-	No	No	NA
A	14	0.40	0.28	0.48	92.86	No	No	Yes
B	30	0.43	0.31	0.58	100	No	No	Yes
I	29	0.425	0.30	0.56	96.55	No	No	Yes
J	28	0.375	0.23	0.48	78.57	No	No	Yes
K	12	0.43	0.34	0.51	100	No	No	Yes
S	34	0.425	0.26	0.52	94.12	No	No	Yes
Avg	34	0.415	0.33	0.46	100	No	No	Yes

Table 18. Results for New23 Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp1	Hyp2	Hyp3
Base	100	0.31	0.14	0.63	-	No	No	NA
A	19	0.44	0.25	0.68	89.47	No	No	Yes
B	38	0.38	0.22	0.74	68.42	No	No	Yes
I	55	0.44	0.20	0.65	74.54	No	No	Yes
J	59	0.41	0.19	0.72	72.88	No	No	Yes
K	38	0.41	0.20	0.61	73.68	No	No	Yes
S	68	0.41	0.13	0.67	83.82	No	No	Yes
Avg	68	0.41	0.30*	0.55	95.59	No	No	Yes

3.3.5 *Chipc1 Image*. None of the subjects' plots resemble Hypothesis One or Two. Additionally, all six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. See Table 19.

Table 19. Results for Chipc1 Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp 1	Hyp 2	Hyp3
Base	100	0.33	0.15	0.63	-	No	No	NA
A	21	0.475	0.22	0.72	95.24	No	No	Yes
B	36	0.51	0.26	0.62	88.89	No	No	Yes
I	50	0.425	0.23	0.64	88.00	No	No	Yes
J	56	0.475	0.17	0.74	87.50	No	No	Yes
K	19	0.45	0.24	0.57	89.47	No	No	Yes
S	31	0.425	0.23	0.61	77.42	No	No	Yes
Avg	56	0.46	0.34*	0.53*	98.21	No	No	Yes

3.3.6 *Chipc2 Image*. One subject's plot, Subject I, resembles Hypothesis Two. Additionally, all six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. See Table 20.

Table 20. Results for Chipc2 Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp 1	Hyp 2	Hyp3
Base	100	0.375	0.18	0.54	-	No	No	NA
A	48	0.475	0.19	0.65	83.33	No	No	Yes
B	13	0.425	0.30	0.52	69.23	No	No	Yes
I	15	0.48	0.20	0.62	86.67	No	Yes	Yes
J	65	0.45	0.17	0.63	86.15	No	No	Yes
K	19	0.44	0.39	0.55	100	No	No	Yes
S	17	0.42	0.23	0.63	82.35	No	No	Yes
Avg	65	0.45	0.33*	0.56*	84.62	No	No	Yes

3.3.7 *New7 Image*. None of the subjects' plots resemble Hypothesis One or Two. Additionally, four out of six subjects and the Average satisfy the acceptance criteria for Hypothesis Three. The two subjects which fail the acceptance criteria for Hypothesis Three are Subjects K and S. Subject K has exactly 50% of its GCC magnitudes above the median of the Baseline while Subject S has only 18.18% of its GCC magnitudes above the median of the Baseline. See Table 21.

At this time it may be instructive to discuss the results of the two candidate data sets which did not satisfy the criteria for Hypothesis Three. The data for these two sets of subject fixation points for the New7 image revealed that the Subjects K and S had only eight and eleven fixations respectively. Eight fixations for this image was the least number of fixations for this image and eleven fixations was the third smallest number of fixations for this image. Subject B

Table 21. Results for New7 Image

Subj	#F/P	Med	Low	High	% > B Med	Hyp 1	Hyp 2	Hyp3
Base	100	0.35	0.12	0.54	-	No	No	NA
A	19	0.525	0.23	0.69	94.74	No	No	Yes
B	9	0.525	0.32	0.67	88.89	No	No	Yes
I	29	0.50	0.21	0.70	93.10	No	No	Yes
J	33	0.475	0.19	0.66	81.82	No	No	Yes
K	8	0.35	0.17	0.55	50.00	No	No	No
S	11	0.31	0.23	0.51	18.18	No	No	No
Avg	33	0.475	0.37*	0.59	96.97	No	No	Yes

had only nine fixations for this image, however, 88.89% of the GCC magnitudes for his fixation points were greater than the median of the Baseline set of fixation points. A quick look at the fixation points of Subject K showed that he is fixating on areas of the image with very little contrast, thus the low GCC magnitudes, see Figure 20. For Subject S, a look at his fixation points revealed that he had few fixations and the fixations were clustered in one area on the image, see Figure 21, while the other four subjects searched the entire image. See Figure 22 for the fixation points of Subject B.

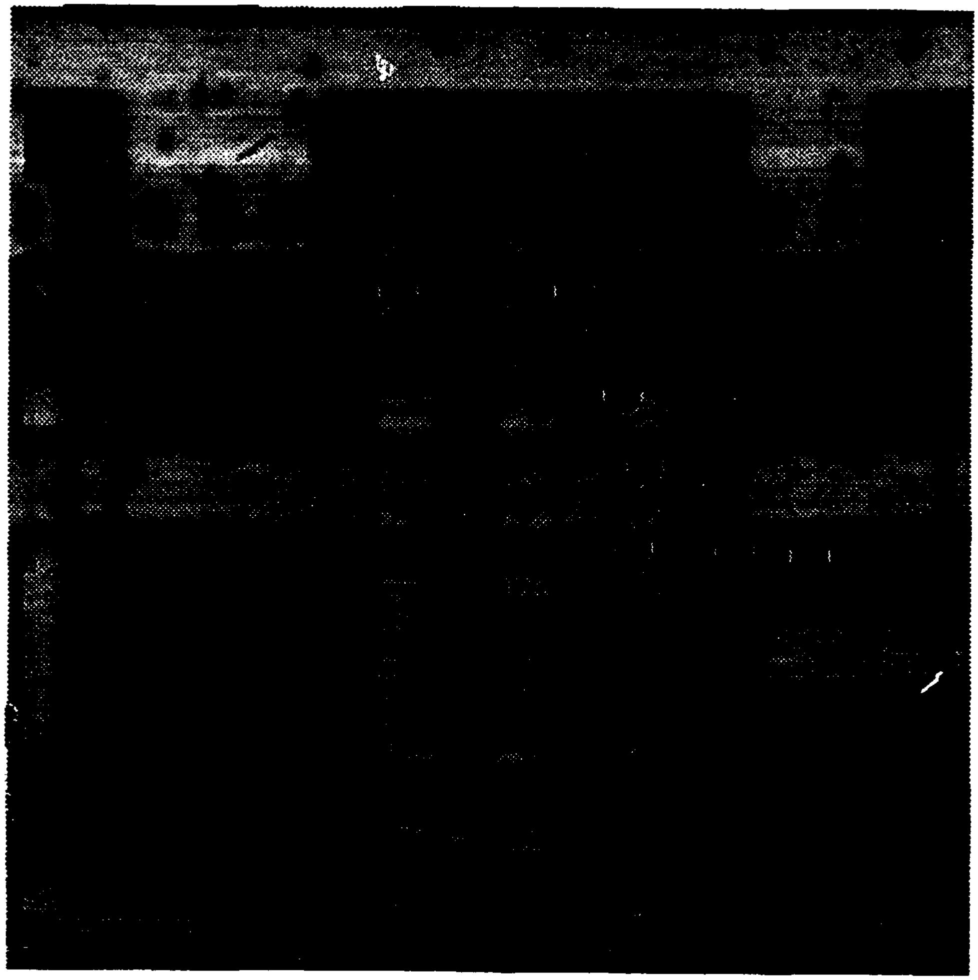

Figure 20. Image New7 with Fixation Points - Subject K

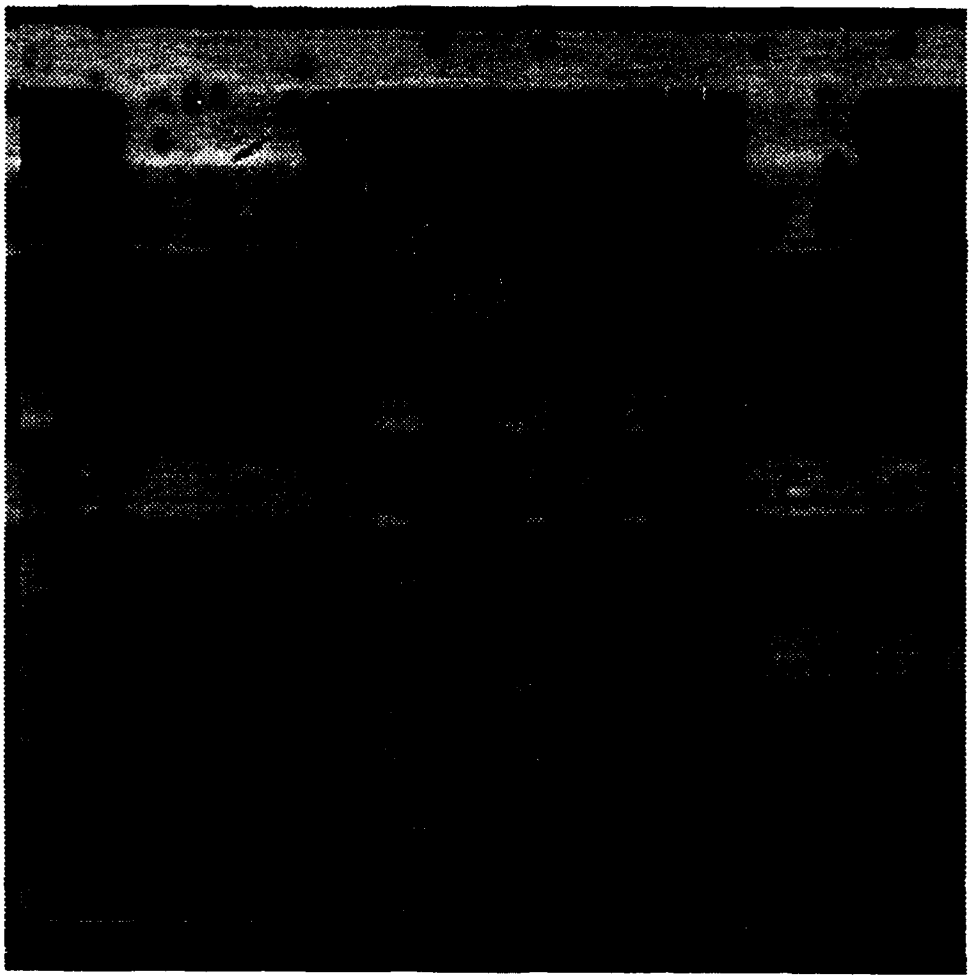

Figure 21. Image New7 with Fixation Points - Subject S

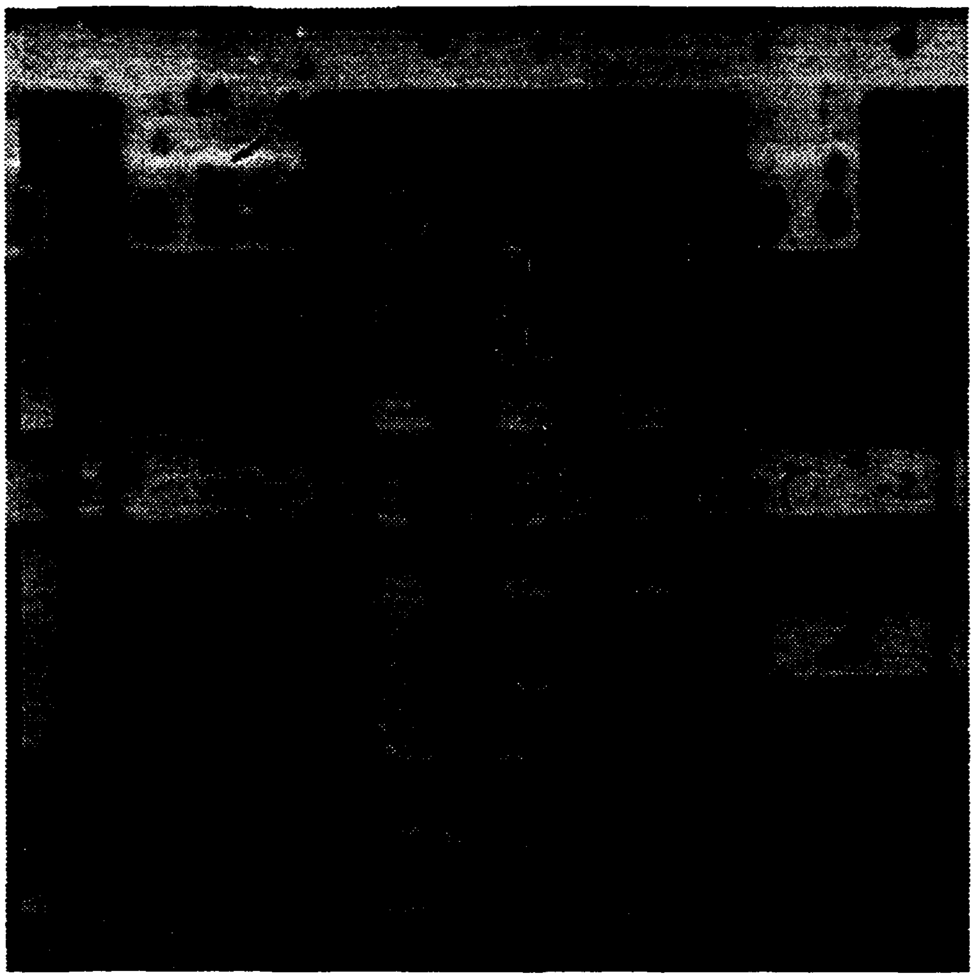

Figure 22. Image New7 with Fixation Points - Subject B

3.4 *Results Tables by Subject*

The following tables summarize the results of the interpretation of the plots in Appendix A and the tables in Section 3.2. These tables contain much of the same information that was in the tables in Section 3.3, however, these tables summarize the information by subject rather than by image. These tables were constructed to facilitate the identification of visual search trends by subject based on GCC magnitudes. Additionally, these tables were constructed to facilitate comparisons between the Baseline and the subjects to ascertain if any significant differences exist.

The average in row nine of these tables is the average of the number of fixation points, the median GCC magnitudes, the low GCC magnitudes, the high GCC magnitudes, and the percentage of GCC magnitudes above the Baseline median for each subject across all seven images.

3.4.1 *Visual Search Trends.* For the most part no significant trends for any particular subject reveal themselves. Subject B's plot of GCC magnitudes for image Mountain satisfies Hypothesis One. Subject I's plot of GCC magnitudes for image Chipc2 satisfies Hypothesis Two. Subject J's plot of GCC magnitudes for images Anna satisfies Hypothesis Two. Subject K's plots do not satisfy Hypothesis One or Two. Also, Subject K fails the acceptance criteria for Hypothesis Three for image New7. Subject S's plot for image Anna satisfies Hypothesis One. Also, Subject S fails the acceptance criteria for Hypothesis Three for image New7. Except for Subjects K and S for image New7, all subjects satisfy the criteria for Hypothesis Three for all images.

3.4.2 *Comparison Between the Baseline Set and the Subjects.* The comparison looked at the average GCC magnitudes for the median, low, and high of the six subjects. The averages of the median GCC magnitudes and the averages of the low GCC magnitudes for all six subjects were greater than the average of the median GCC magnitudes and the average of the low GCC magnitudes of the Baseline. The average of the high GCC magnitude for Subject K was the only average of the high GCC magnitudes which were less than the average of the high GCC magnitude of the Baseline.

Table 22. Results for Baseline

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	100	0.26	0.13	0.47	-	No	No	NA
Mountain	100	0.26	0.12	0.49	-	No	No	NA
Cobra	100	0.31	0.18	0.53	-	No	No	NA
New23	100	0.31	0.14	0.63	-	No	No	NA
Chipc1	100	0.33	0.15	0.63	-	No	No	NA
Chipc2	100	0.375	0.18	0.54	-	No	No	NA
New7	100	0.35	0.12	0.54	-	No	No	NA
Average	100	0.314	0.146	0.547	-	-	-	-

Table 23. Results for Subject A

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	9	0.37	0.26	0.47	100	No	No	Yes
Mountain	36	0.36	0.28	0.51	100	No	No	Yes
Cobra	14	0.40	0.28	0.48	92.86	No	No	Yes
New23	19	0.44	0.25	0.68	89.47	No	No	Yes
Chipc1	21	0.475	0.22	0.72	95.24	No	No	Yes
Chipc2	48	0.475	0.19	0.65	83.33	No	No	Yes
New7	19	0.525	0.23	0.69	94.74	No	No	Yes
Average	23.7	0.435	0.244	0.600	93.66	-	-	-

Table 24. Results for Subject B

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	33	0.375	0.29	0.54	100	No	No	Yes
Mountain	26	0.37	0.28	0.48	100	Yes	No	Yes
Cobra	30	0.43	0.31	0.58	100	No	No	Yes
New23	38	0.38	0.22	0.74	68.42	No	No	Yes
Chipc1	36	0.51	0.26	0.62	88.89	No	No	Yes
Chipc2	13	0.425	0.30	0.52	69.23	No	No	Yes
New7	9	0.525	0.32	0.67	88.89	No	No	Yes
Average	26.4	0.431	0.283	0.593	87.92	-	-	-

Table 25. Results for Subject I

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	28	0.425	0.28	0.57	100	No	No	Yes
Mountain	31	0.45	0.25	0.51	96.77	No	No	Yes
Cobra	29	0.425	0.30	0.56	96.55	No	No	Yes
New23	55	0.44	0.20	0.65	74.54	No	No	Yes
Chipc1	50	0.425	0.23	0.64	88.00	No	No	Yes
Chipc2	15	0.48	0.20	0.62	86.67	No	Yes	Yes
New7	29	0.50	0.21	0.70	93.10	No	No	Yes
Average	34.0	0.449	0.239	0.607	90.80	-	-	-

Table 26. Results for Subject J

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	46	0.375	0.27	0.57	100	No	Yes	Yes
Mountain	56	0.375	0.25	0.51	98.21	No	No	Yes
Cobra	28	0.375	0.23	0.48	78.57	No	No	Yes
New23	59	0.41	0.19	0.72	72.88	No	No	Yes
Chipc1	56	0.475	0.17	0.74	87.50	No	No	Yes
Chipc2	65	0.45	0.17	0.63	86.15	No	No	Yes
New7	33	0.475	0.19	0.66	81.82	No	No	Yes
Average	49.0	0.419	0.210	0.616	86.45	-	-	-

Table 27. Results for Subject K

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	11	0.36	0.29	0.46	100	No	No	Yes
Mountain	13	0.39	0.26	0.47	92.31	No	No	Yes
Cobra	12	0.43	0.34	0.51	100	No	No	Yes
New23	38	0.41	0.20	0.61	73.68	No	No	Yes
Chipc1	19	0.45	0.24	0.57	89.47	No	No	Yes
Chipc2	19	0.44	0.39	0.55	100	No	No	Yes
New7	8	0.35	0.17	0.55	50.00	No	No	No
Average	17.1	0.404	0.270	0.531	86.49	-	-	-

Table 28. Results for Subject S

Image	#F/P	Med	Low	High	% > Base Med	Hyp 1	Hyp 2	Hyp 3
Anna	33	0.425	0.26	0.56	100	Yes	No	Yes
Mountain	51	0.37	0.26	0.47	98.04	No	No	Yes
Cobra	34	0.425	0.26	0.52	94.12	No	No	Yes
New23	68	0.41	0.13	0.67	83.82	No	No	Yes
Chipc1	31	0.425	0.23	0.61	77.42	No	No	Yes
Chipc2	17	0.42	0.23	0.63	82.35	No	No	Yes
New7	11	0.31	0.23	0.51	18.18	No	No	No
Average	35.0	0.398	0.229	0.567	79.13	-	-	-

3.5 *GCC Magnitude Comparisons Between the Beginning and the End of the Subject Visual Search*

One of the questions posed as a result of Captain Fretheim's doctoral research was, are the GCC magnitudes for the subject fixation points at the beginning of the visual search greater than the GCC magnitudes for the subject fixation points at the end of the visual search? From the plots of the GCC magnitudes plotted against the time ordered subject fixation points, the answer appeared to be no and, therefore, a simple analysis of the data was performed. The simple analysis included calculating the means of the GCC magnitudes at the beginning and the end of the visual search for the six subjects. The results are summarized in tabular form in the following two sections. Section 3.5.1 summarizes the results by image an Section 3.5.2 summarizes the results by subject. The means of the GCC magnitudes at the beginning and the end of the visual search for the six subjects were then compared.

3.5.1 *Comparison Results by Image.* Tables 29 - 35 summarize the results by image of the means of the GCC magnitudes for the beginning and the end of the subject visual search. For the Anna image, Table 29, five out of six subjects have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For the Mountain and

Chipc1 images, Tables 30 and 33 respectively, two out of six subjects have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For the Cobra, New23, and Chipc2 images, Tables 31, 32, and 34 respectively, three out of six subjects have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For the New7 image, Table 35, four out of six subjects have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. There does not appear to be a predominant trend in the comparison between the GCC magnitudes at the beginning and the end of the subject visual search. These results support the conclusion drawn from examining the plots in Appendix A.

Table 29. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Anna Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.367866	0.411249
Subject B	0.390660	0.386541
Subject I	0.452322	0.412929
Subject J	0.431588	0.360576
Subject K	0.370810	0.344260
Subject S	0.410664	0.410118

Table 30. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Mountain Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.367245	0.366542
Subject B	0.389535	0.370031
Subject I	0.392256	0.419326
Subject J	0.367904	0.378674
Subject K	0.375610	0.391259
Subject S	0.358170	0.389127

Table 31. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Cobra Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.410145	0.388598
Subject B	0.450474	0.400775
Subject I	0.400439	0.445620
Subject J	0.362752	0.389424
Subject K	0.431581	0.425811
Subject S	0.416538	0.419475

Table 32. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - New23 Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.444994	0.431592
Subject B	0.389410	0.418009
Subject I	0.389026	0.412772
Subject J	0.399682	0.441077
Subject K	0.388141	0.385979
Subject S	0.418074	0.417926

Table 33. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Chipc1 Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.459203	0.501701
Subject B	0.493294	0.488944
Subject I	0.427742	0.434001
Subject J	0.451084	0.476889
Subject K	0.465889	0.439627
Subject S	0.412721	0.426790

Table 34. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Chipc2 Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.451679	0.457632
Subject B	0.423055	0.403225
Subject I	0.521055	0.391730
Subject J	0.468911	0.446275
Subject K	0.436252	0.465541
Subject S	0.418516	0.446555

Table 35. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - New7 Image

Subject	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Subject A	0.529138	0.531654
Subject B	0.513801	0.519732
Subject I	0.519365	0.484062
Subject J	0.472143	0.441893
Subject K	0.370666	0.343336
Subject S	0.317126	0.315475

3.5.2 *Comparison Results by Subject.* Tables 36 - 41 summarize the results by subject of the means of the GCC magnitudes for the beginning and the end of the subject visual search. For Subject A, Table 36, four out of seven images have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For Subject B, Table 37, five out of seven images have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For Subject I, Table 38, three out of seven images have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For Subject J, Table 39, three out of seven images have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For Subject K, Table 40, five out of seven images have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. For Subject S, Table 41, three out of seven images have a mean GCC magnitude which was greater at the beginning of the visual search than at the end of the visual search. There does not appear to be a predominant trend in the comparison between the GCC magnitudes at the beginning and the end of the subject visual search. Again, these results support the conclusion drawn from examining the plots in Appendix A.

Table 36. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Subject A

Image	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Anna	0.367866	0.411249
Mountain	0.367245	0.366542
Cobra	0.410145	0.388598
New23	0.444994	0.431592
Chipc1	0.459203	0.501701
Chipc2	0.451679	0.457632
New7	0.529138	0.531654

Table 37. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Subject B

Image	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Anna	0.390660	0.386541
Mountain	0.389535	0.370031
Cobra	0.450474	0.409775
New23	0.389410	0.418009
Chipc1	0.493294	0.488944
Chipc2	0.423055	0.403225
New7	0.513801	0.519732

Table 38. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Subject I

Image	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Anna	0.452322	0.412929
Mountain	0.392256	0.419326
Cobra	0.400439	0.445620
New23	0.389026	0.412772
Chipc1	0.427742	0.434001
Chipc2	0.521055	0.391730
New7	0.519365	0.484062

Table 39. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Subject J

Image	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Anna	0.431588	0.360576
Mountain	0.367904	0.378674
Cobra	0.362752	0.389424
New23	0.399682	0.441077
Chipc1	0.451084	0.476889
Chipc2	0.468911	0.446275
New7	0.472143	0.441893

Table 40. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Subject K

Image	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Anna	0.370810	0.344260
Mountain	0.375610	0.391259
Cobra	0.431581	0.425811
New23	0.388141	0.385979
Chipc1	0.465889	0.439627
Chipc2	0.436252	0.465541
New7	0.370666	0.343336

Table 41. Comparison of the Means of the GCC Magnitudes at the Beginning and End of the Visual Search - Subject S

Image	Mean of GCC Magnitudes Beginning of Search	Mean of GCC Magnitudes End of Search
Anna	0.410664	0.410118
Mountain	0.358170	0.389127
Cobra	0.416538	0.419475
New23	0.418074	0.417926
Chipc1	0.412721	0.426790
Chipc2	0.418516	0.446555
New7	0.317126	0.315475

IV. *Conclusions and Recommendations*

4.1 *Conclusions*

A number of questions arose as a result of Captain Fretheim's doctoral research and it was these questions that lead to the performance of this thesis. Therefore, it might be constructive to refresh the reader's memory by restating these questions.

First, is there a definitive relationship between the strength of the GCC and the time ordered sequence of the fixation points of the human subjects? Second, can the human search strategy be modelled based on the magnitude of the GCC for the features contained within an image? Third, is there a well defined relationship between the strength of the GCC at the beginning and end of an image search or, said another way, are the magnitudes of the GCC at the beginning of the visual search greater than the magnitudes of the GCC at the end of the visual search? Last, if the answer to any of these questions is yes, how can the Gabor transform be used to develop a reliable model for the human visual system search strategy?

4.1.1 *Hypothesis One Conclusions.* Hypothesis One stated that the initial visual search strategy can be predicted based on the relative GCC magnitudes of the subject fixation points. The GCC magnitudes for the human subject fixation points would be highest at the beginning of the visual search, the GCC magnitudes would then linearly decrease for the next couple fixation points, and at some point the magnitude of the GCC for the subsequent fixation points would alternate between high and low values.

From the results in Section 3.3, Tables 15 - 21, it was observed that only one out of the forty-two of the subject plots, six subjects and seven images, resemble Hypothesis One. Hypothesis One can not be supported based on the plots. It was concluded that no definitive relationship exists between the GCC magnitudes and the time ordered sequence of the subject fixation points. Therefore, the GCC magnitude can not be used to predict the time ordered sequence of human fixation points.

4.1.2 *Hypothesis Two Conclusions.* Hypothesis Two stated that the first few, three or less for the purpose of this thesis, fixation points are random. However, after these first few fixation points, the ensuing visual search strategy could be predicted based on the relative GCC magnitudes of the fixation points. The GCC magnitudes for the human subject fixation points would be highest at the beginning of the visual search, the GCC magnitudes would then linearly decrease for the next several fixation points, and at some point the magnitude of the GCC for the subsequent fixation points would alternate between high and low values.

From the results in Section 3.3, Tables 15 - 21, it was observed that only two out of the forty-two subject plots, six subjects and seven images, resemble Hypothesis Two. Hypothesis Two can not be supported based on the plots. It was concluded that no definitive relationship exists between the GCC magnitudes and the time ordered sequence of the subject fixation points, even after the first couple of fixation have been performed. Therefore, the GCC magnitude can not be used to predict the time ordered sequence of human fixation points.

4.1.3 *Hypothesis Three Conclusions.* The GCC magnitudes of the subject fixation points do not predict the time ordered sequence of the subject fixation points. However, the majority (greater than 50%) of the GCC magnitudes of the subject fixation points are greater than the median of the GCC magnitudes of the random set of fixation points.

The acceptance criteria for this hypothesis was that more than 50% of the GCC magnitudes for the subject fixation points must be distributed above the median of the GCC magnitudes of the Baseline set of fixation points.

As it turns out, the data analysis results supported Hypothesis Three. From Section 3.2, Tables 1 - 14 as well as the summarized results in Tables 15 - 21, it was observed that forty out of forty-two sets of subject data satisfy the acceptance criteria for Hypothesis Three. Specifically, these tables show that eleven out of forty-two sets of subject data have more than 100% of their GCC magnitudes distributed above the median of the GCC magnitudes for the random set of fixation points. Also, these tables show that twenty-one out of forty-two sets of subject data have more than 90% of their GCC distributed above the mean of the Baseline set of fixation points.

And, these tables show that thirty-three out of the forty-two sets of data have 80% of their GCC magnitudes distributed above the median of the Baseline set of fixation points. Therefore, the GCC magnitudes for the subject fixation points were greater than the GCC magnitudes for a random set of fixation points, i.e., the Baseline set of fixation points. This data indicates that the GCC magnitudes of the subject fixation points could be used, judiciously, to indicate where potential human fixation points might reside in an image.

4.1.4 *GCC Magnitude Comparison Conclusions.* From the results of Section 3.5, Tables 29 - 41, it was concluded that their is no definitive trend in the comparison between the GCC magnitudes at the beginning and the end of the subject visual search. As a matter of fact, from the tables, it was observed that twenty-two of the forty-two sets of subject data had means of the GCC magnitudes which were greater at the beginning of the visual search than the means of the GCC magnitudes at the end of the visual search.

4.2 *Recommendations*

The results of this research indicate that the human visual search strategy is formed by the individual based on the semanics of the image being searched as well as the instructions he may receive prior to beginning the search task. The results also indicate that the specific areas of the image that the searcher fixates have relatively, at least with respect to a random set of fixation points, large GCC magnitudes. These results give rise to another question which may require additional research. The question being: If the visual search strategy is formed based on the semantics of the image and the instructions to the searcher, does the GCC magnitude play a role in predicting precisely where the searcher will fixate on the image? In other words, does the searcher direct his attention to a general location on the image and then the precise fixation location is determined by the point with the largest GCC magnitude within this general region?

Appendix A: *Plots*

Appendix A contains the plots used to perform the comparisons described in Section 3.1.

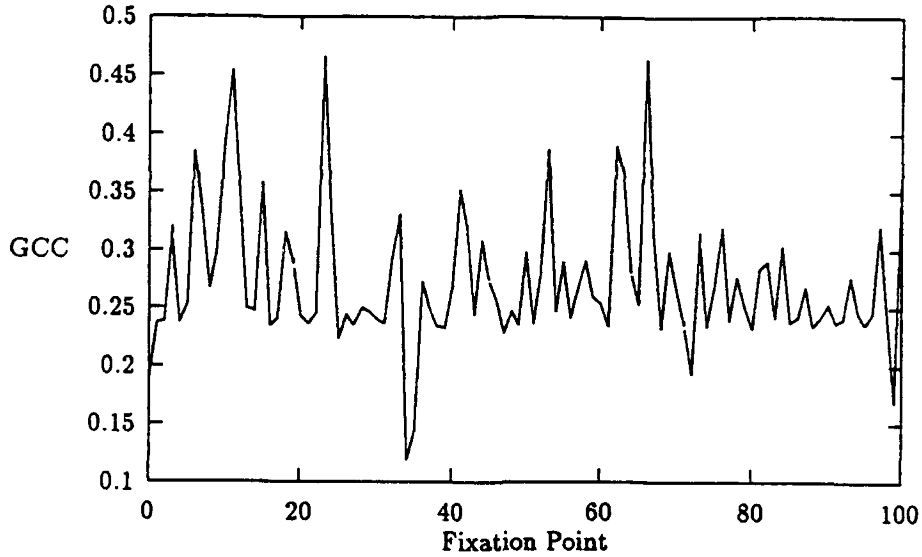

Figure 23. Plot of Baseline - Anna Image

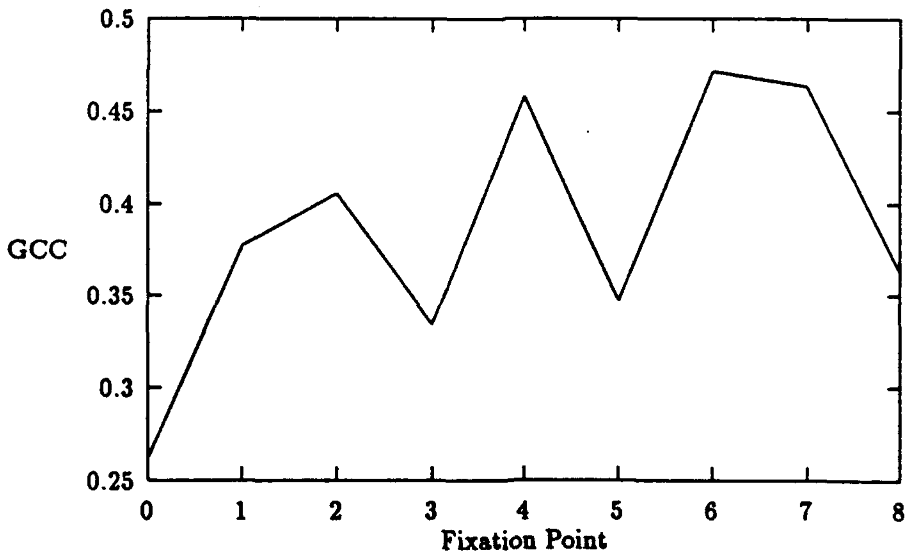

Figure 24. Plot of Subject A - Anna Image

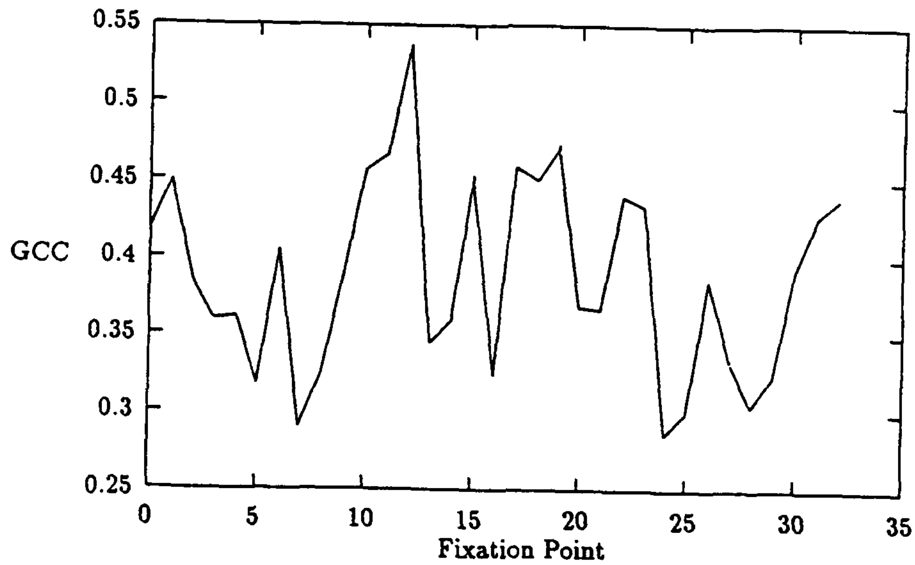

Figure 25. Plot of Subject B - Anna Image

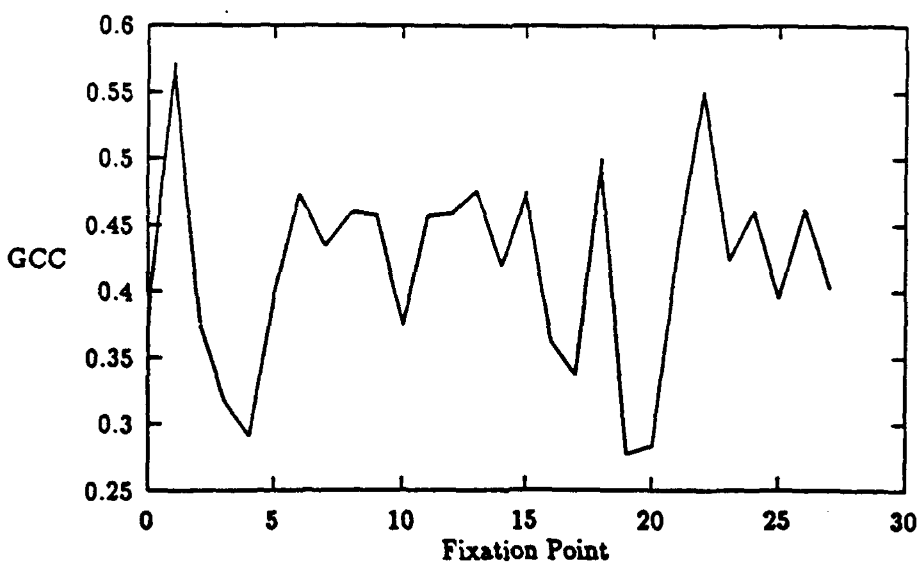

Figure 26. Plot of Subject I - Anna Image

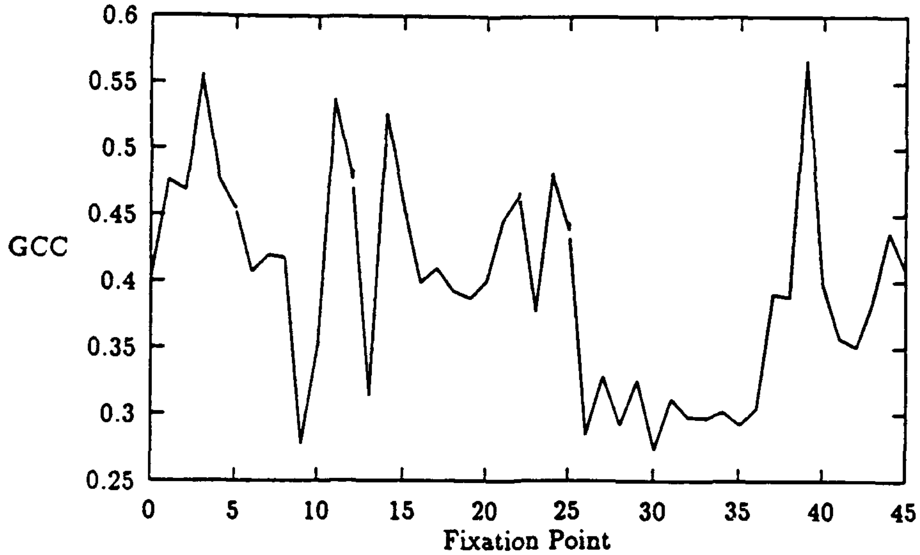

Figure 27. Plot of Subject J - Anna Image

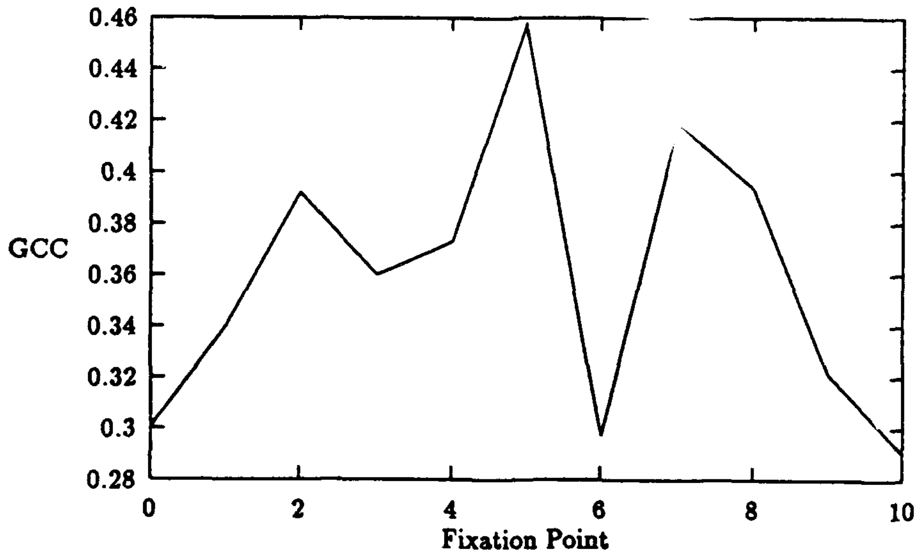

Figure 28. Plot of Subject K - Anna Image

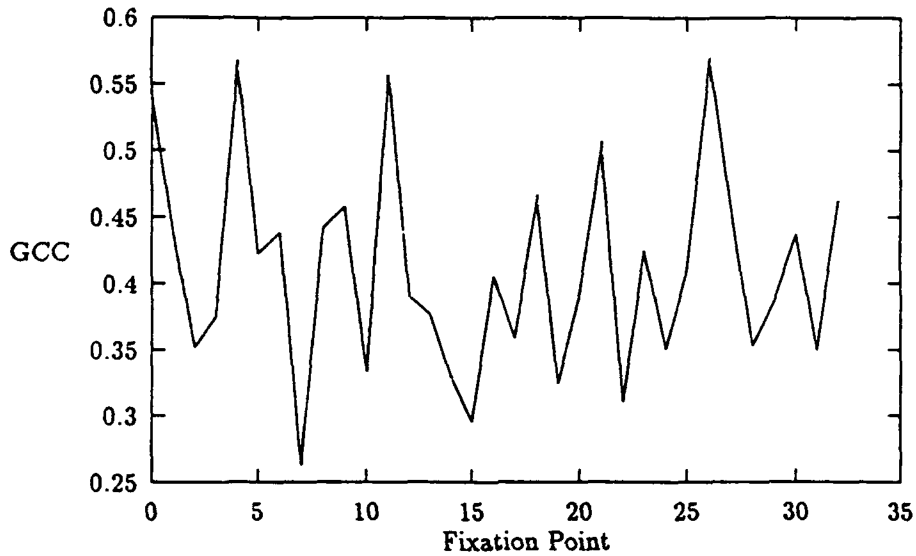

Figure 29. Plot of Subject S - Anna Image

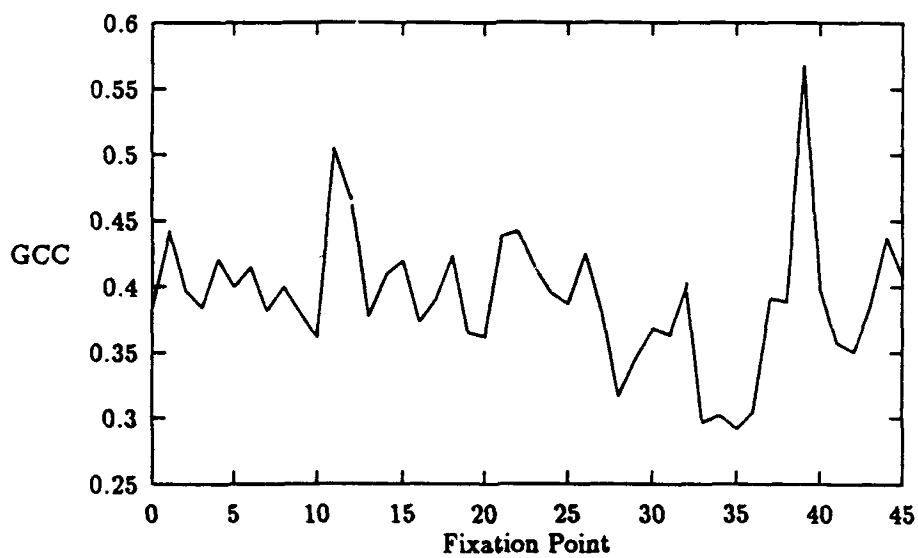

Figure 30. Plot of Average - Anna Image

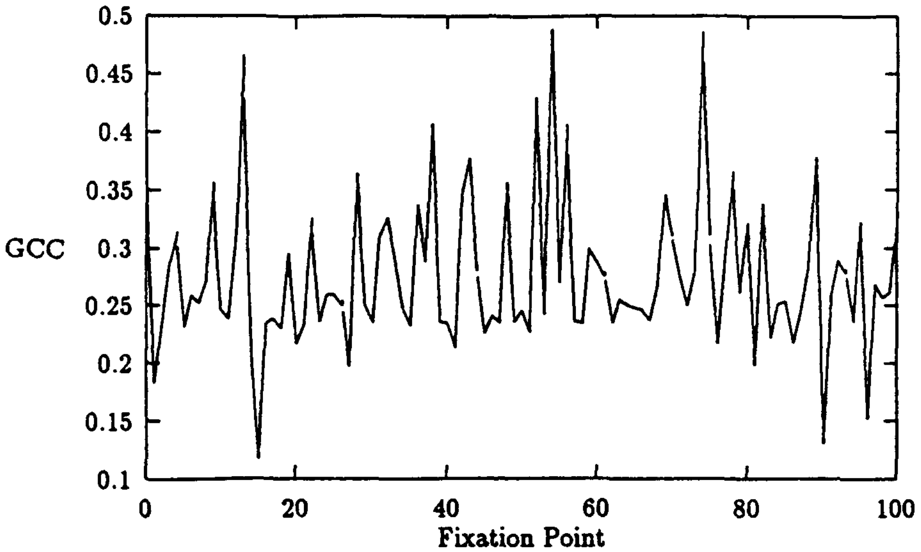

Figure 31. Plot of Baseline - Mountain Image

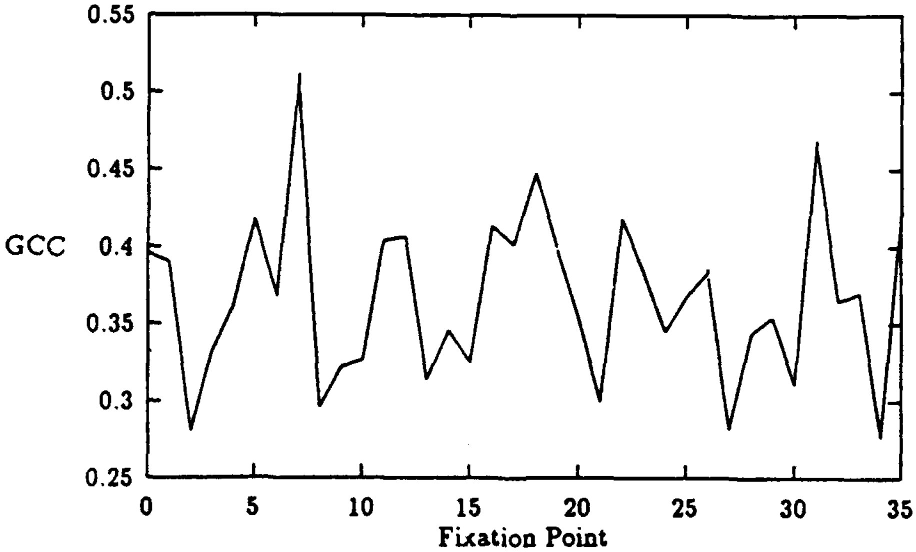

Figure 32. Plot of Subject A - Mountain Image

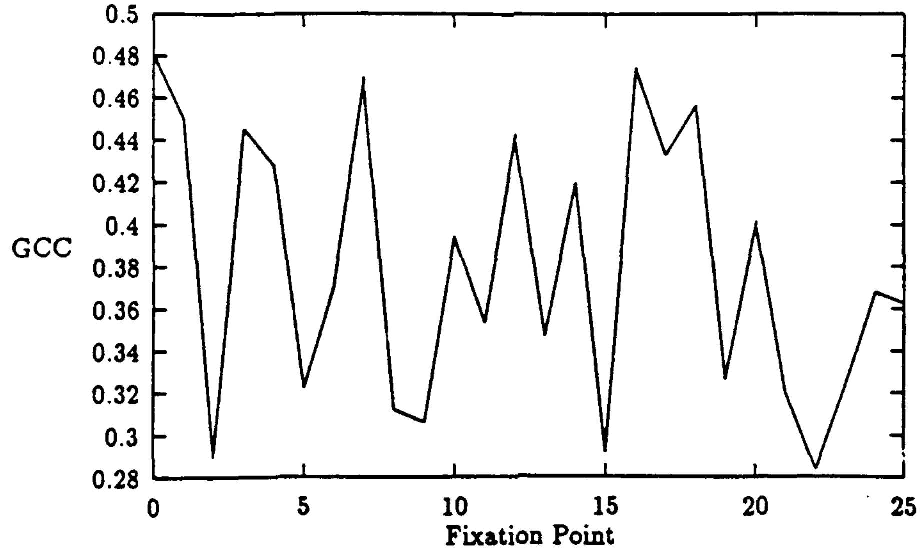

Figure 33. Plot of Subject B - Mountain Image

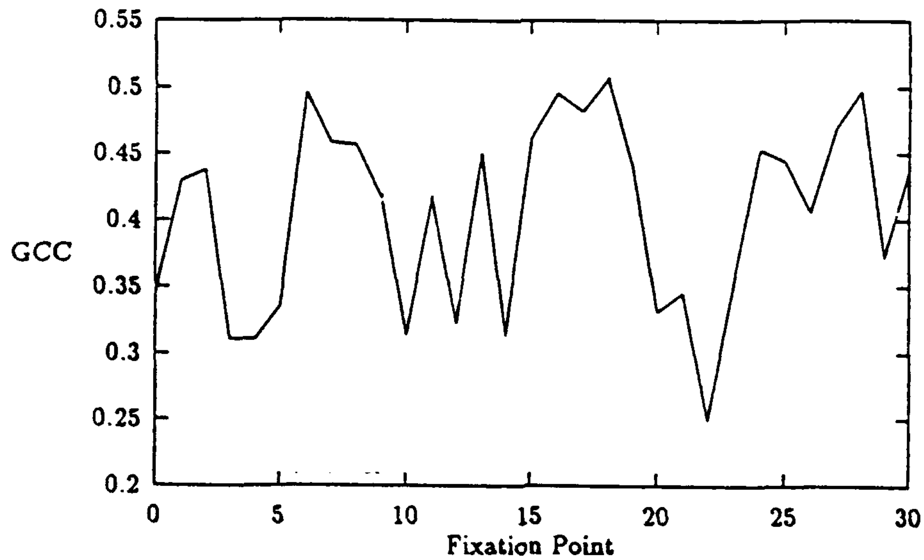

Figure 34. Plot of Subject I - Mountain Image

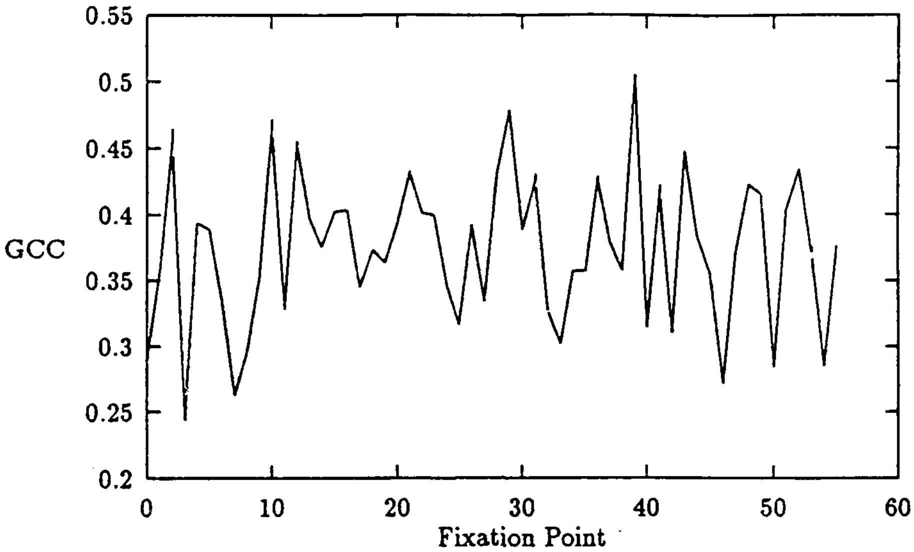

Figure 35. Plot of Subject J - Mountain Image

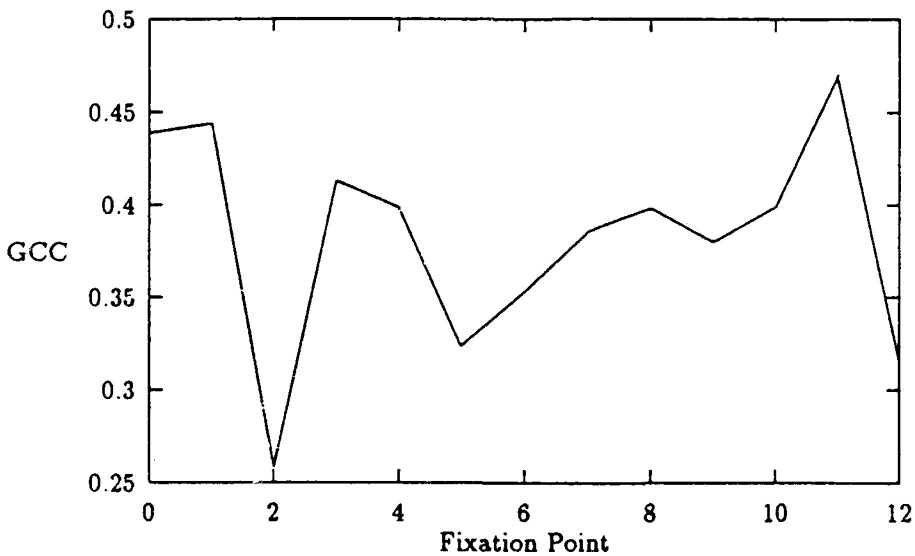

Figure 36. Plot of Subject K - Mountain Image

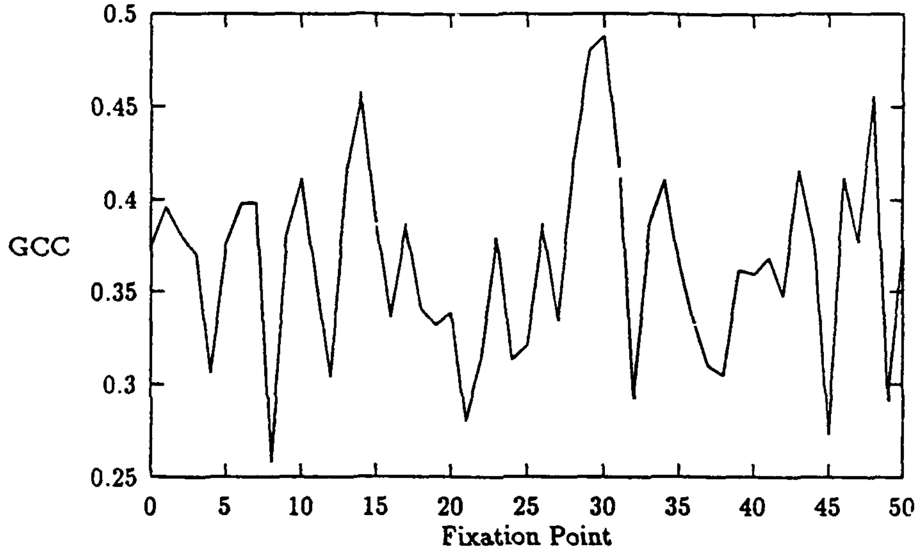

Figure 37. Plot of Subject S - Mountain Image

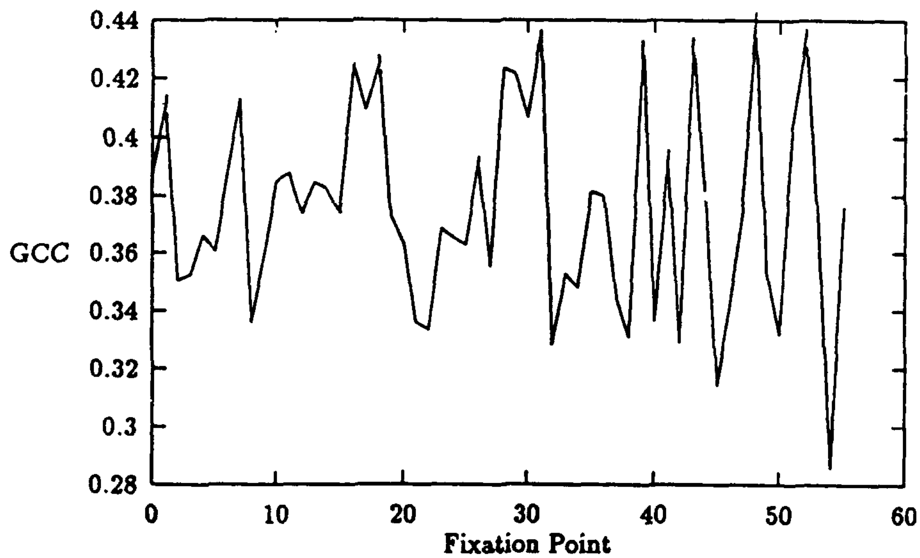

Figure 38. Plot of Average - Mountain Image

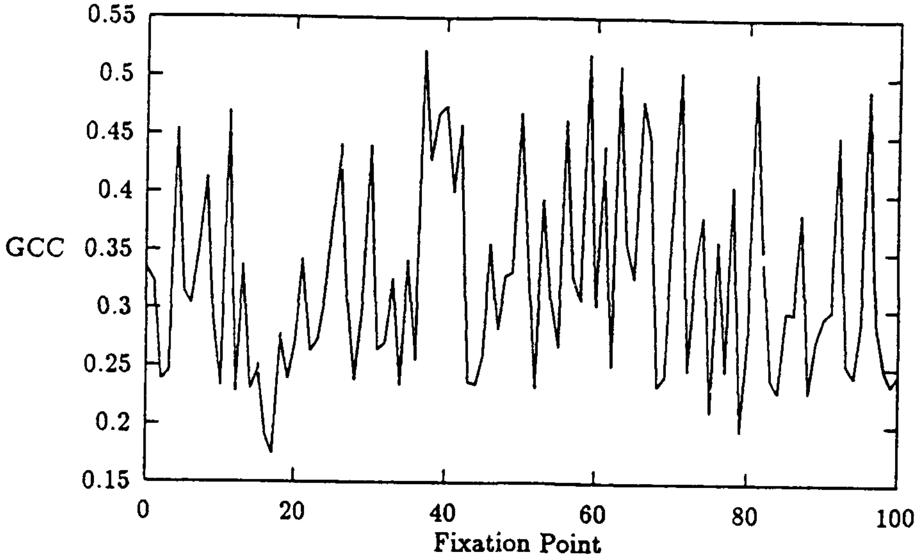

Figure 39. Plot of Baseline - Cobra Image

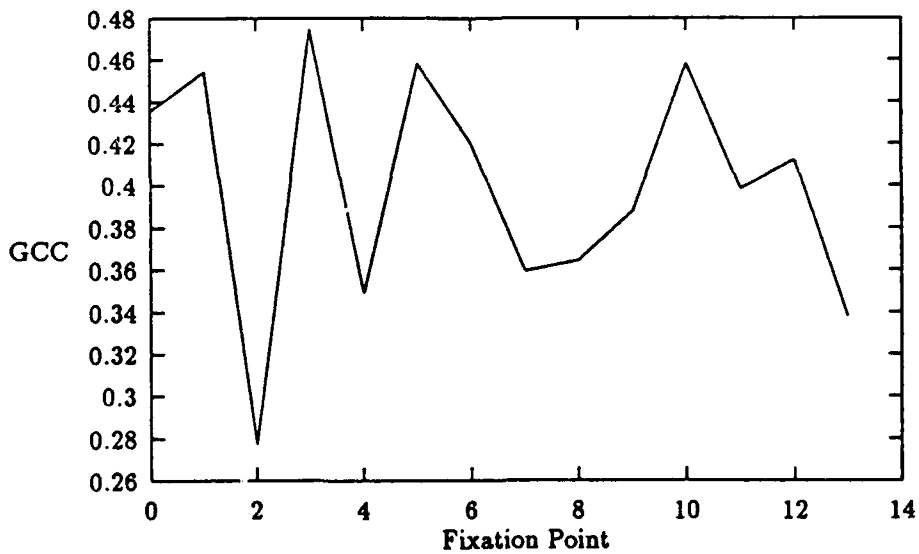

Figure 40. Plot of Subject A - Cobra Image

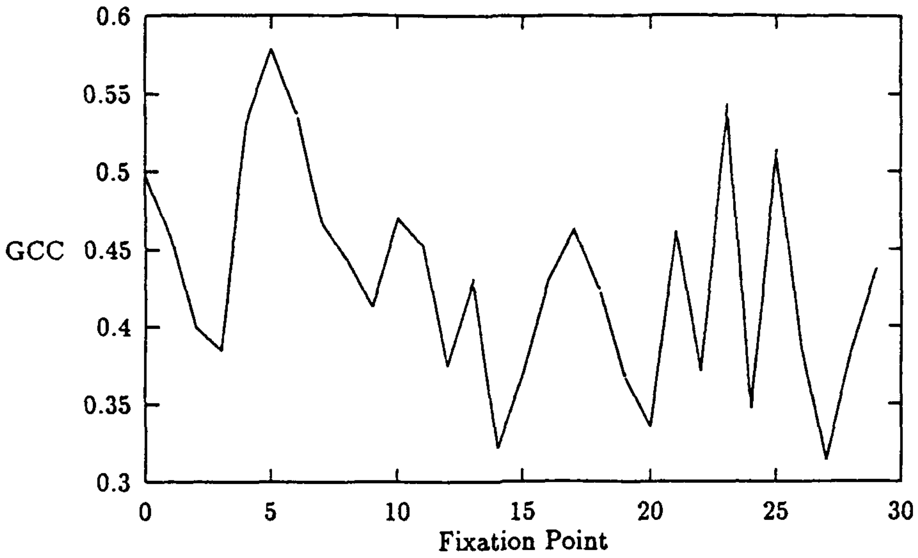

Figure 41. Plot of Subject B - Cobra Image

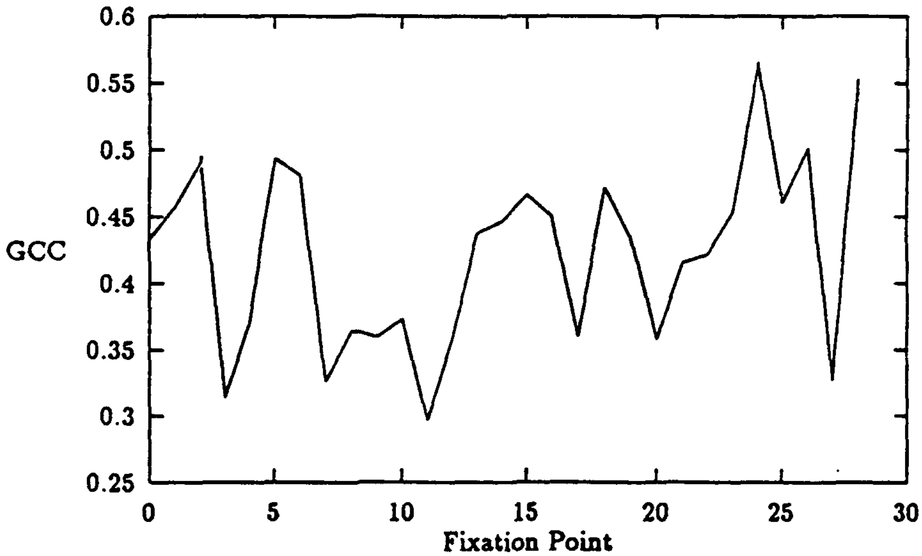

Figure 42. Plot of Subject I - Cobra Image

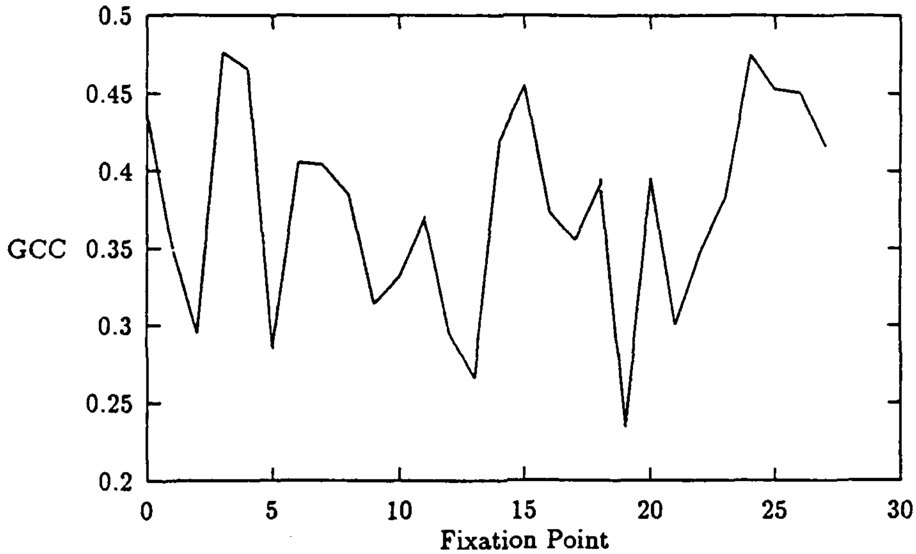

Figure 43. Plot of Subject J - Cobra Image

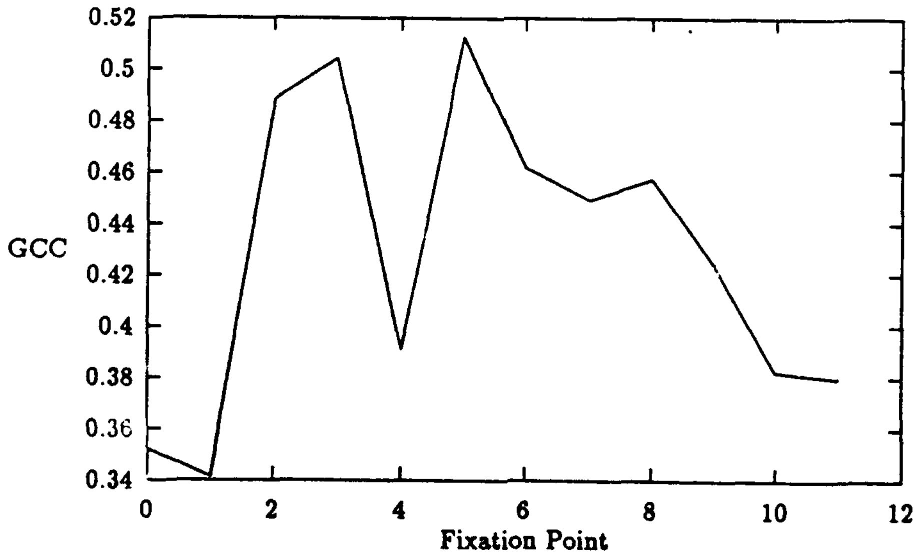

Figure 44. Plot of Subject K - Cobra Image

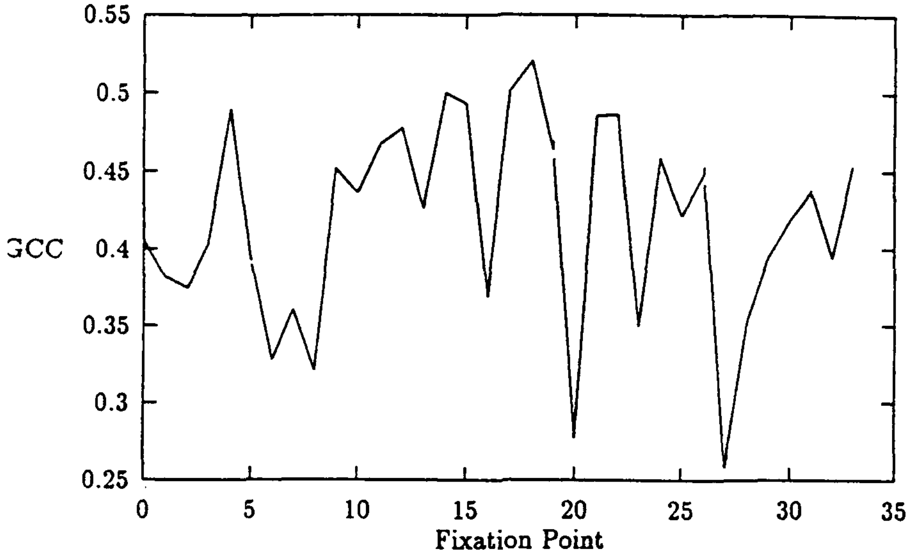

Figure 45. Plot of Subject S - Cobra Image

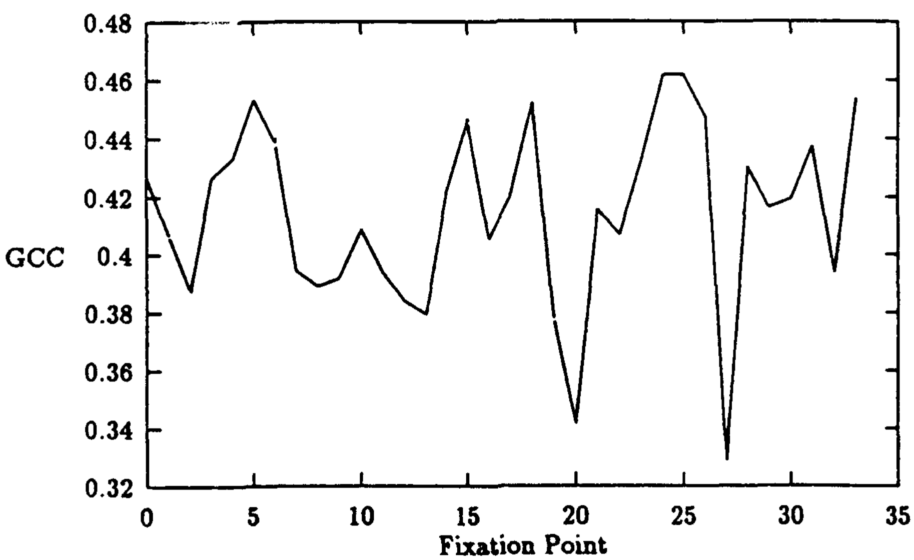

Figure 46. Plot of Average - Cobra Image

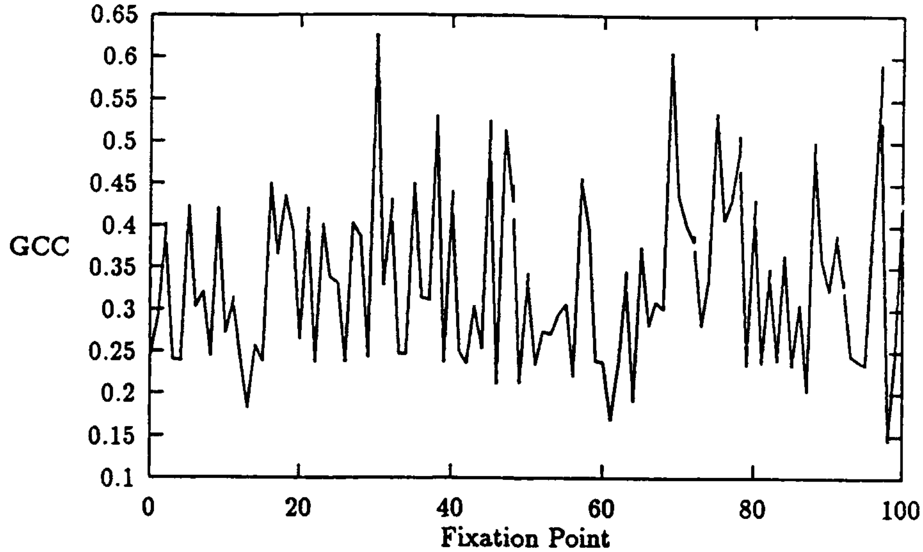

Figure 47. Plot of Baseline - New23 Image

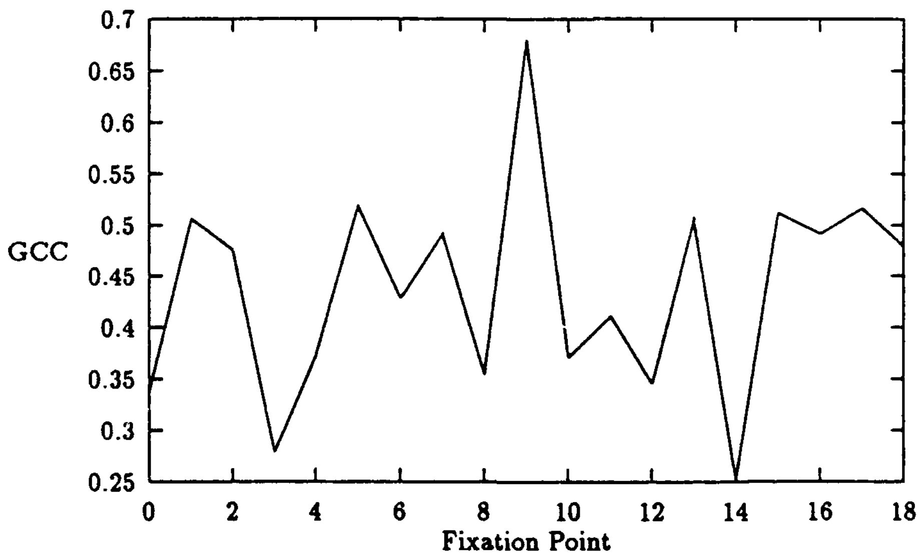

Figure 48. Plot of Subject A - New23 Image

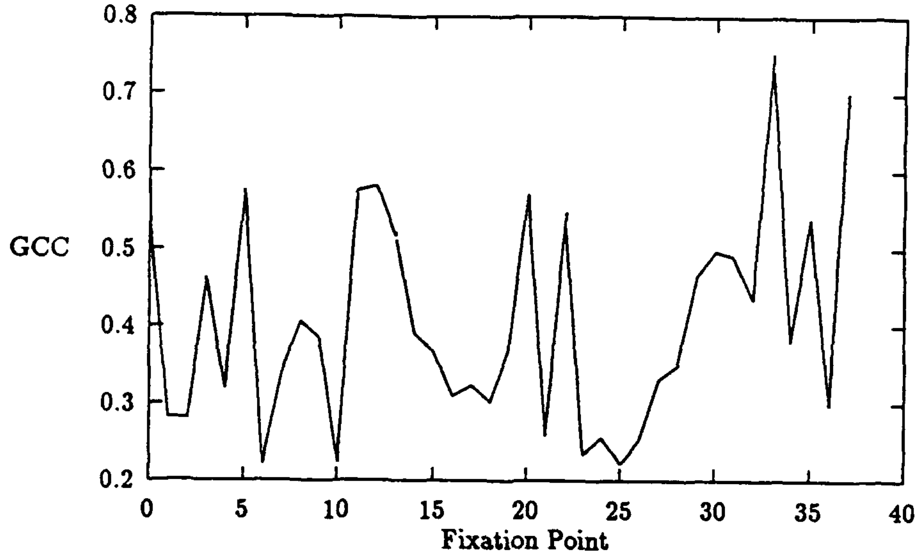

Figure 49. Plot of Subject B - New23 Image

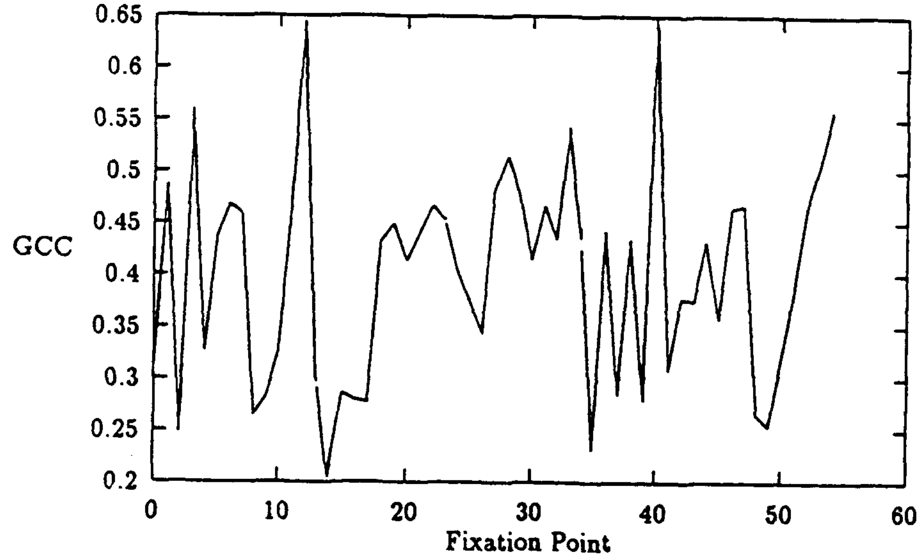

Figure 50. Plot of Subject I - New23 Image

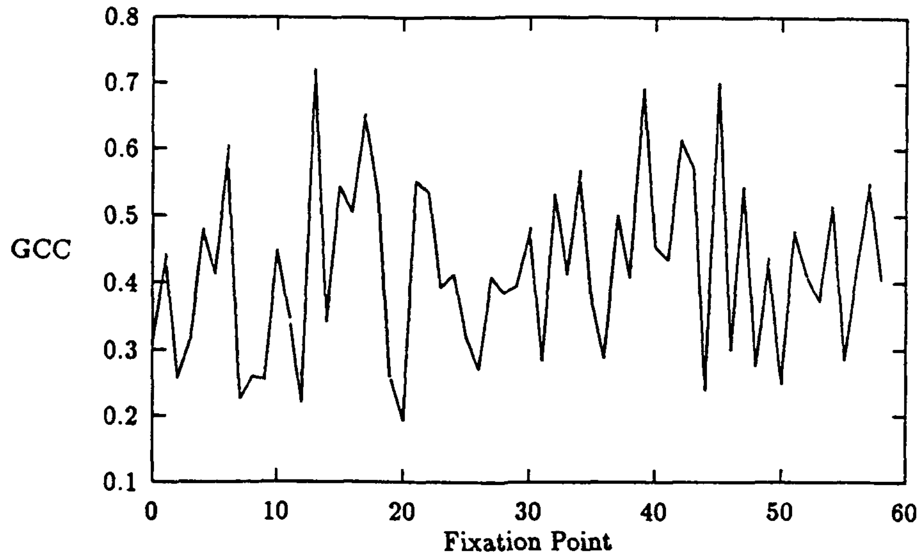

Figure 51. Plot of Subject J - New23 Image

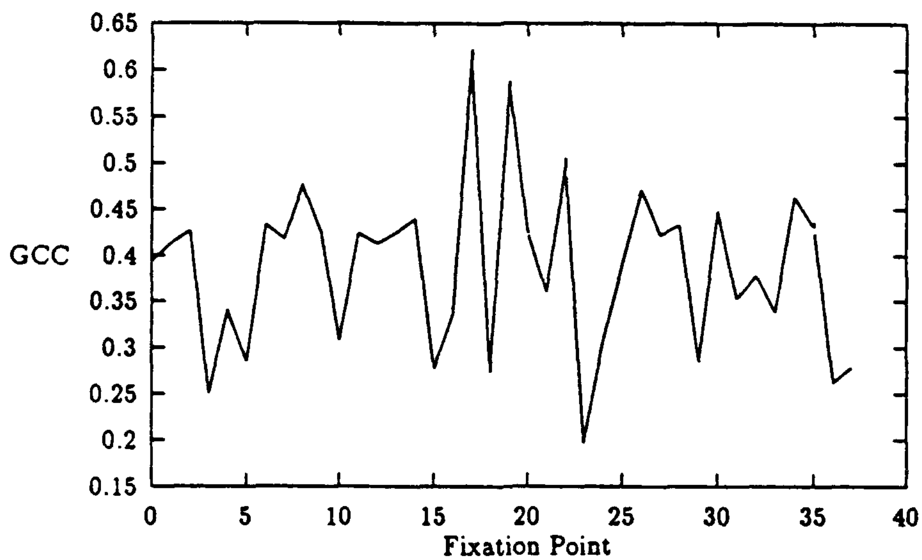

Figure 52. Plot of Subject K - New23 Image

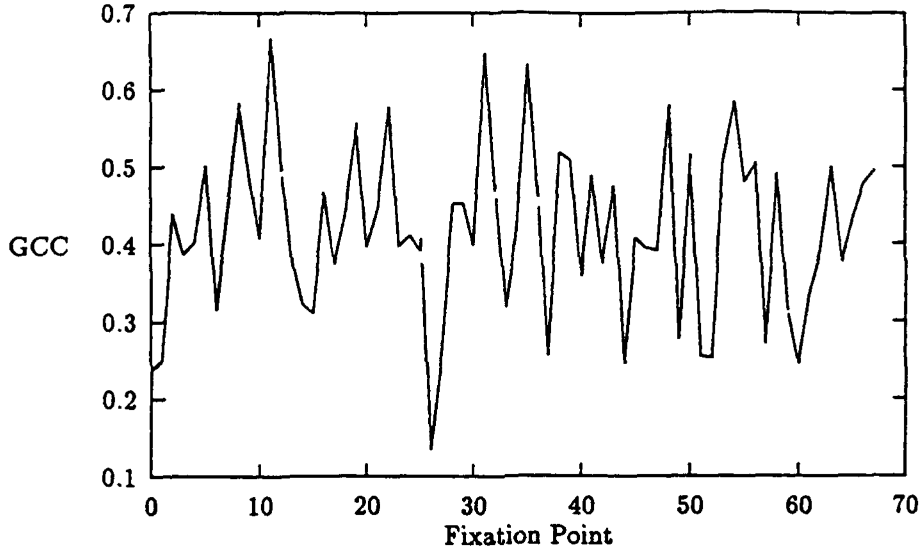

Figure 53. Plot of Subject S - New23 Image

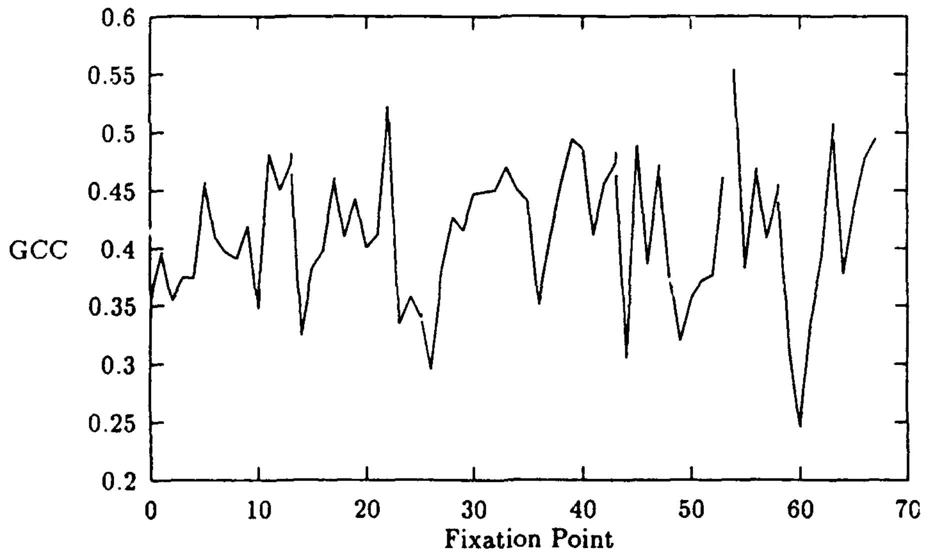

Figure 54. Plot of Average - New23 Image

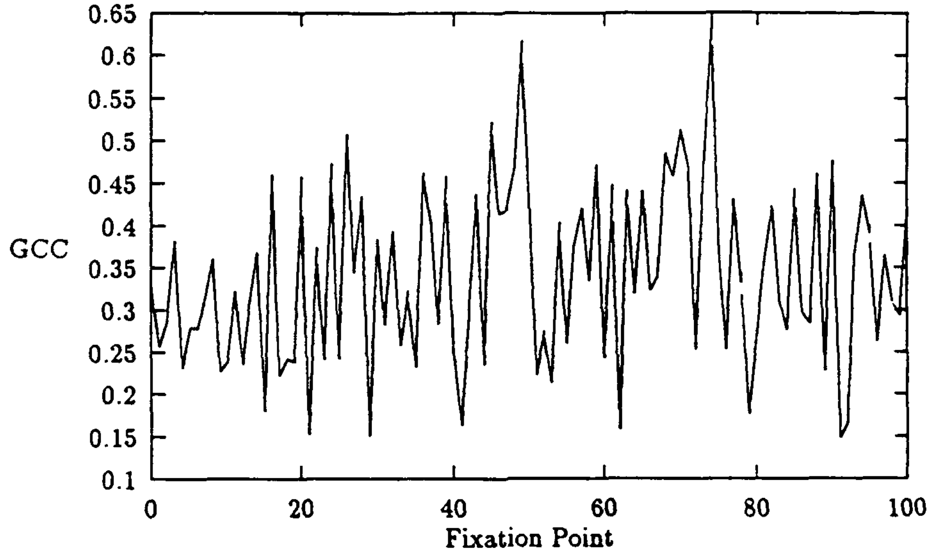

Figure 55. Plot of Baseline - Chipc1 Image

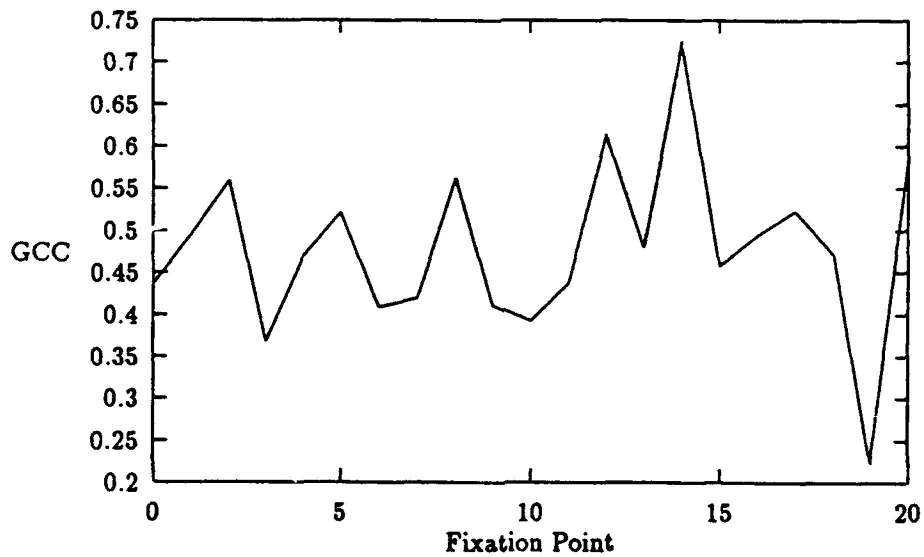

Figure 56. Plot of Subject A - Chipc1 Image

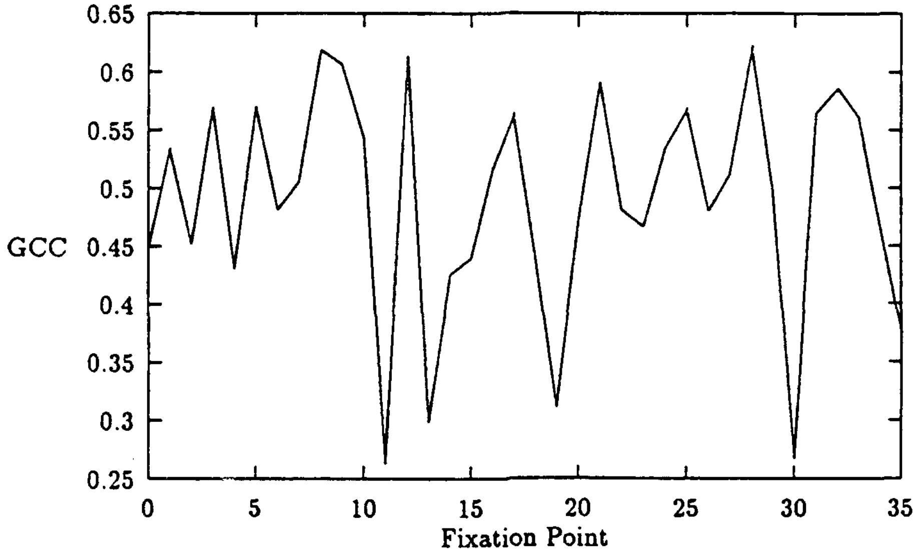

Figure 57. Plot of Subject B - Chipc1 Image

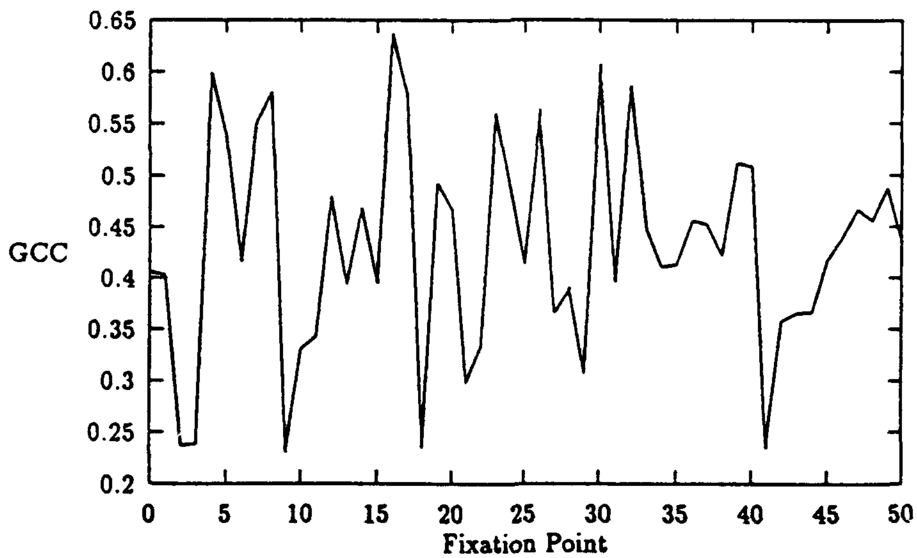

Figure 58. Plot of Subject I - Chipc1 Image

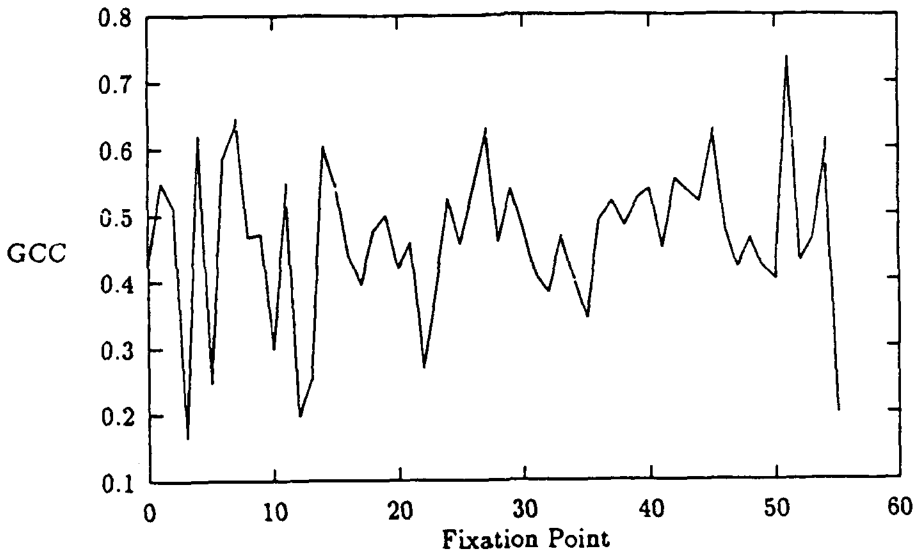

Figure 59. Plot of Subject J - Chipc1 Image

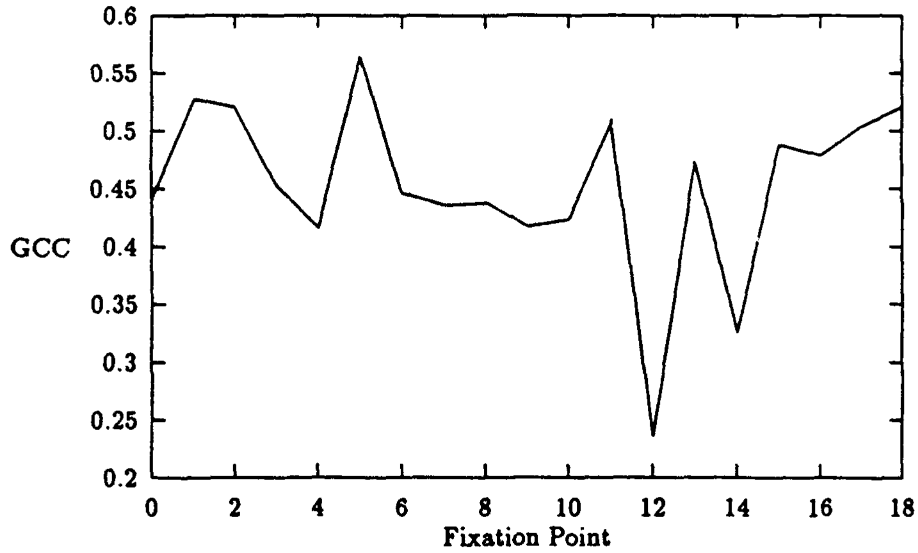

Figure 60. Plot of Subject K - Chipc1 Image

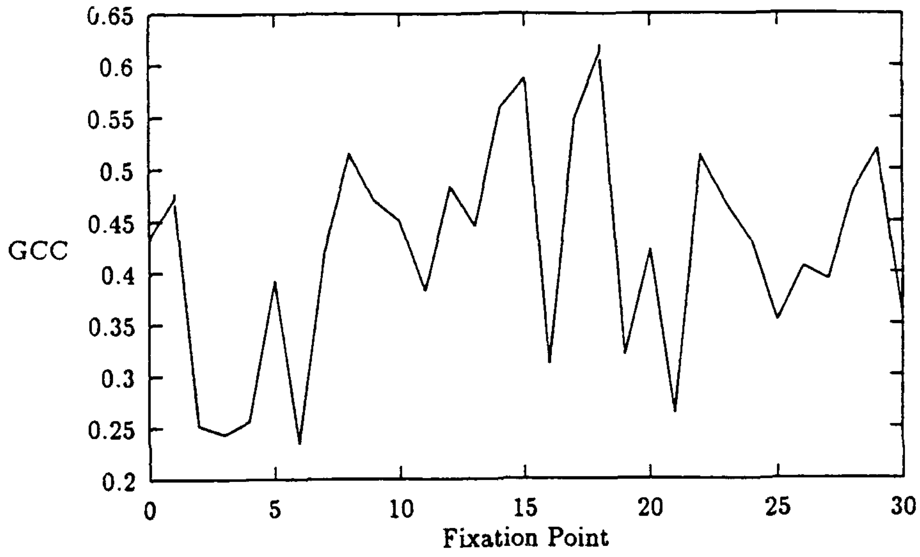

Figure 61. Plot of Subject S - Chipcl Image

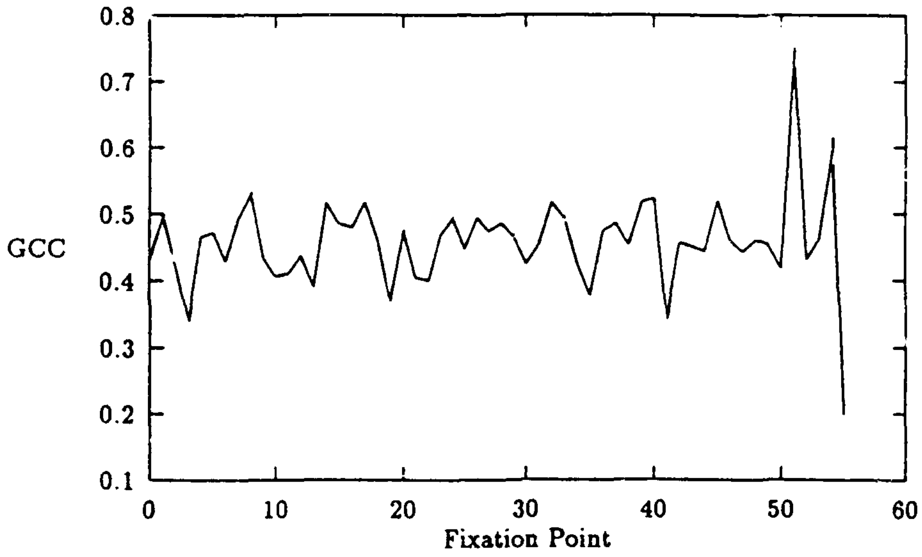

Figure 62. Plot of Average - Chipcl Image

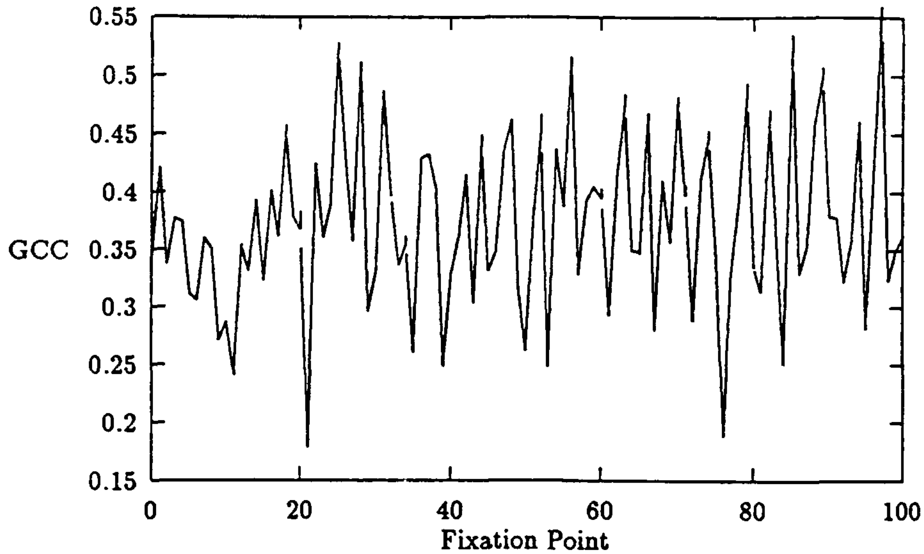

Figure 63. Plot of Baseline - Chipc2 Image

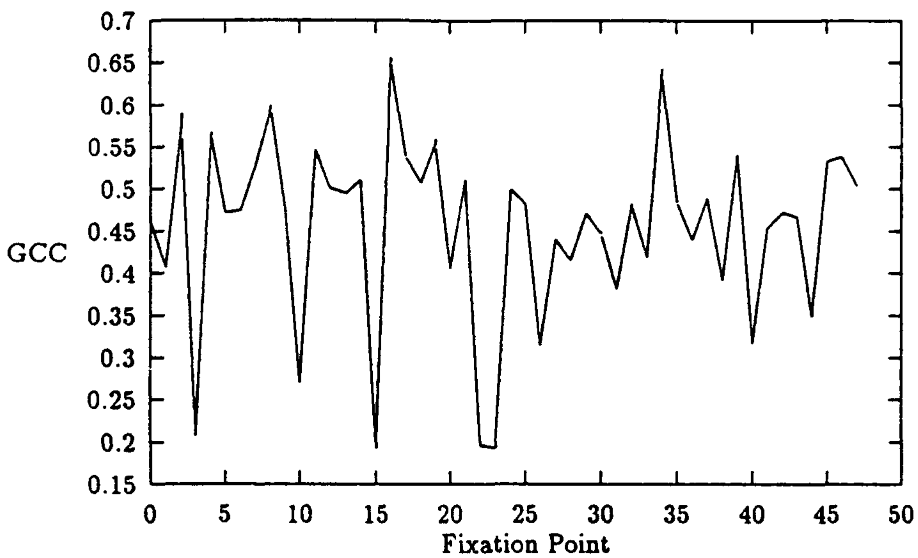

Figure 64. Plot of Subject A - Chipc2 Image

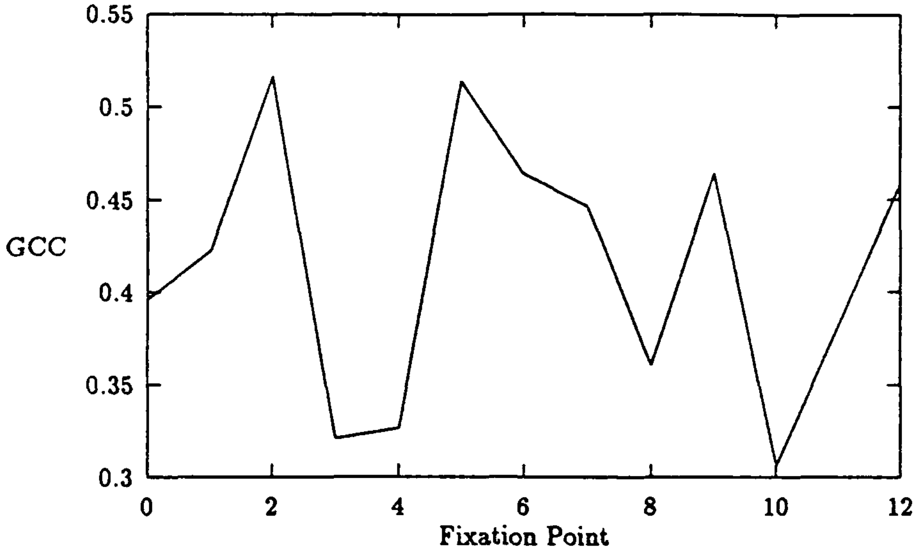

Figure 65. Plot of Subject B - Chipc2 Image

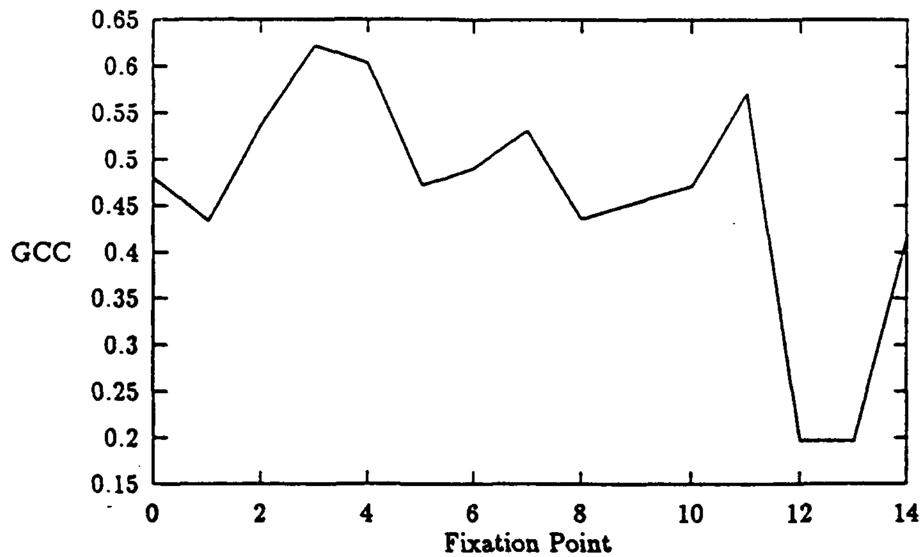

Figure 66. Plot of Subject I - Chipc2 Image

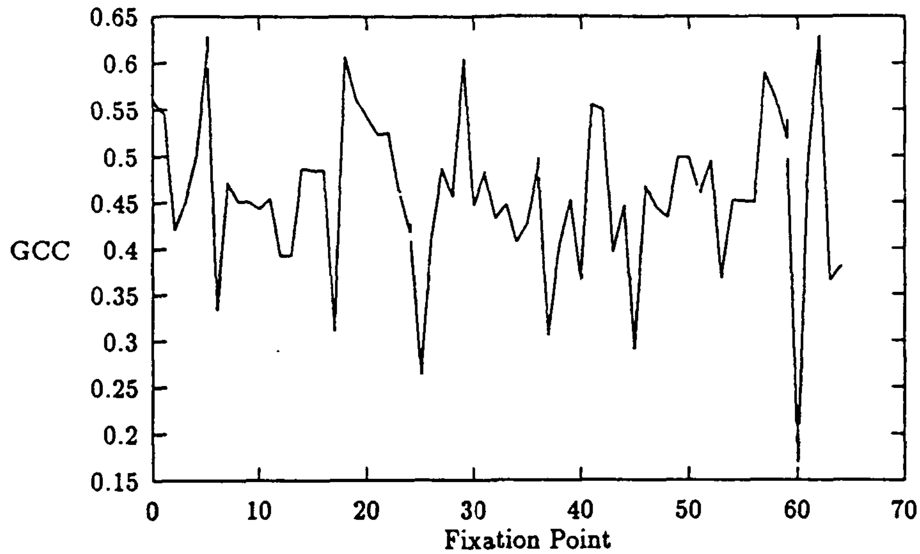

Figure 67. Plot of Subject J - Chipc2 Image

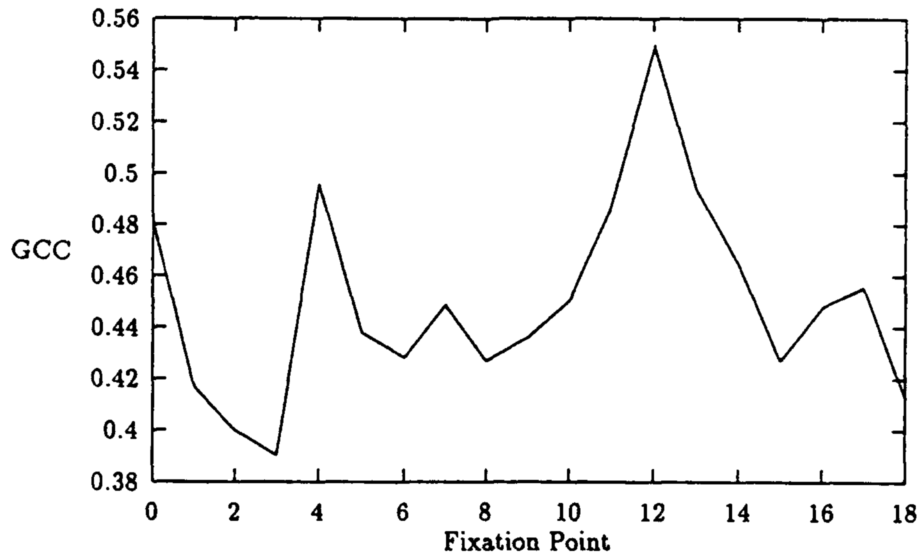

Figure 68. Plot of Subject K - Chipc2 Image

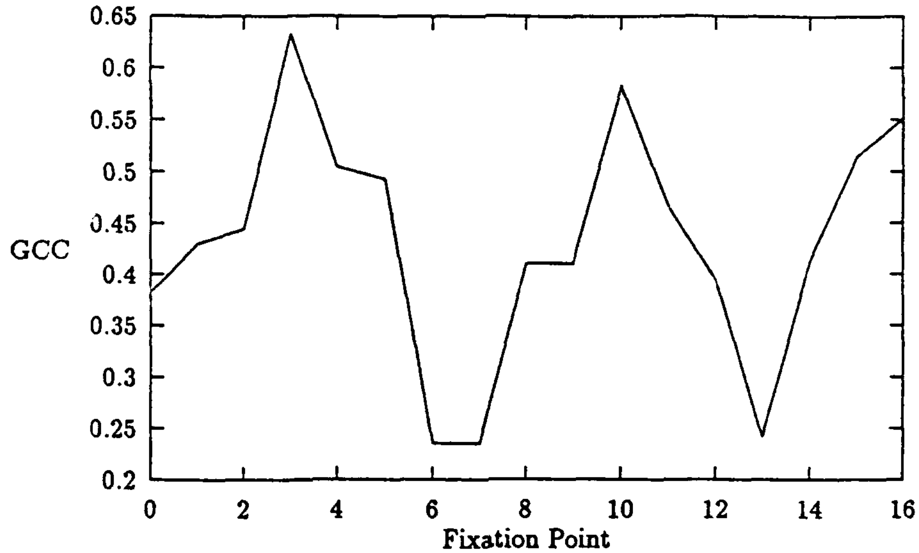

Figure 69. Plot of Subject S - Chipc2 Image

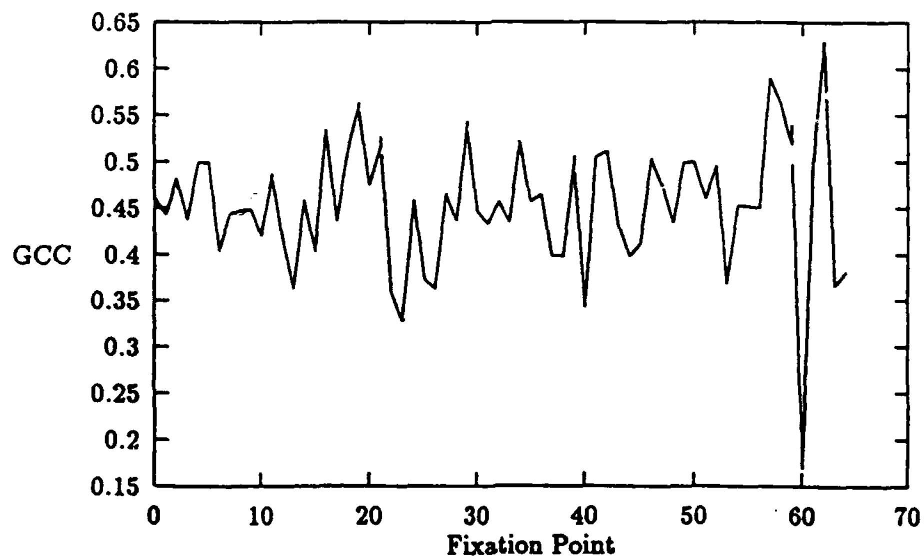

Figure 70. Plot of Average - Chipc2 Image

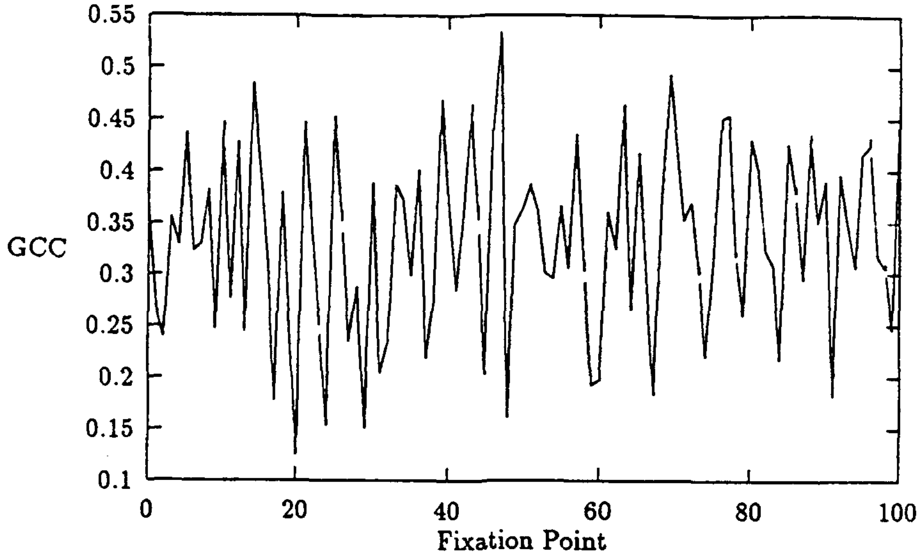

Figure 71. Plot of Baseline - New7 Image

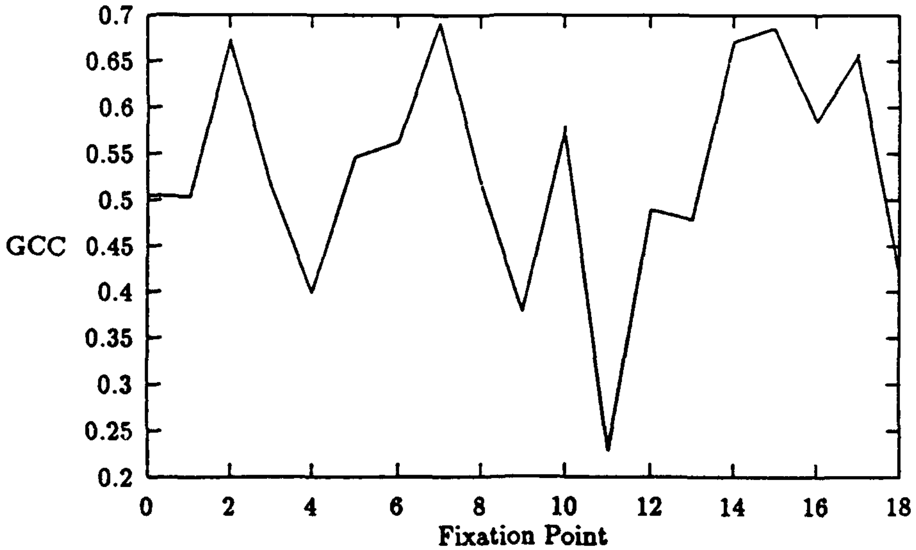

Figure 72. Plot of Subject A - New7 Image

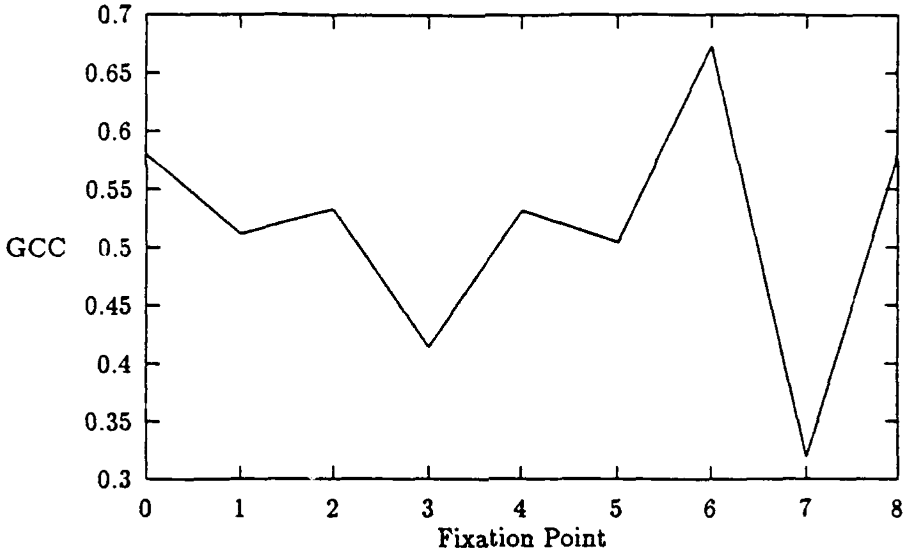

Figure 73. Plot of Subject B - New7 Image

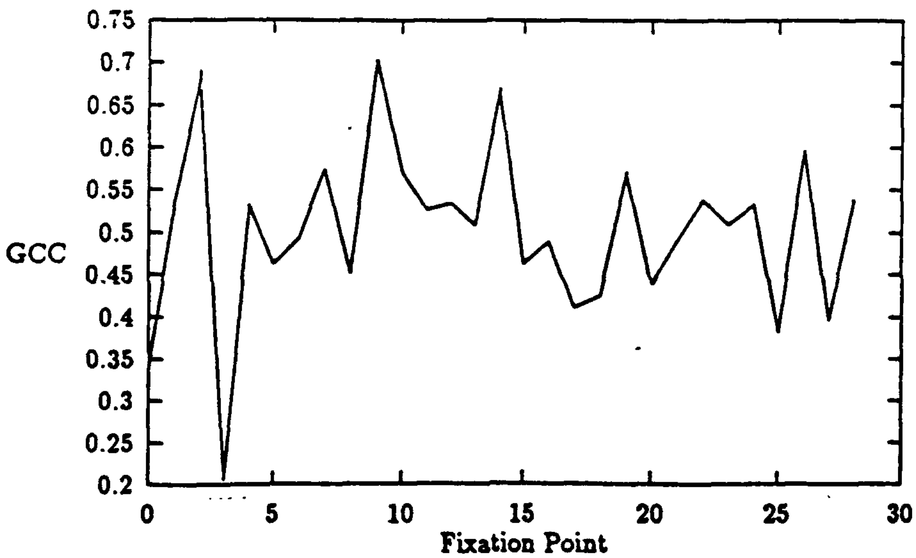

Figure 74. Plot of Subject I - New7 Image

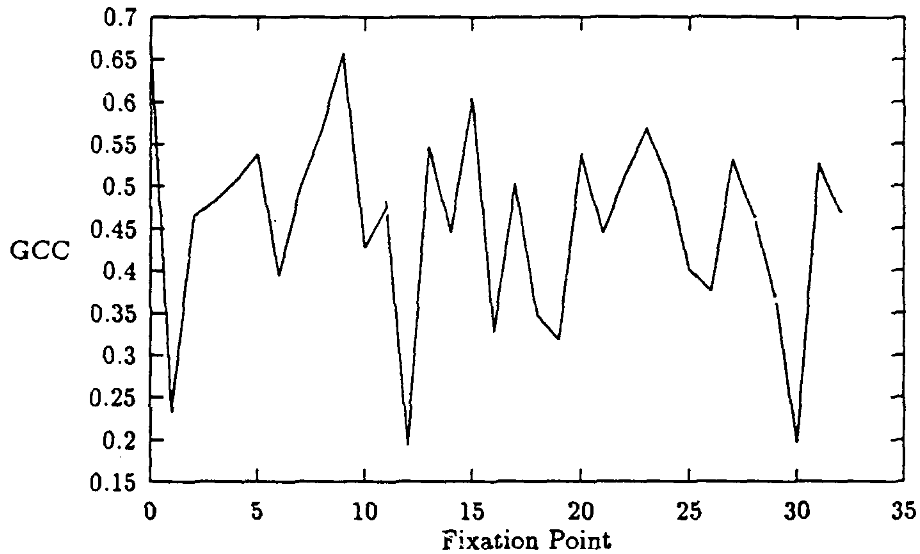

Figure 75. Plot of Subject J - New7 Image

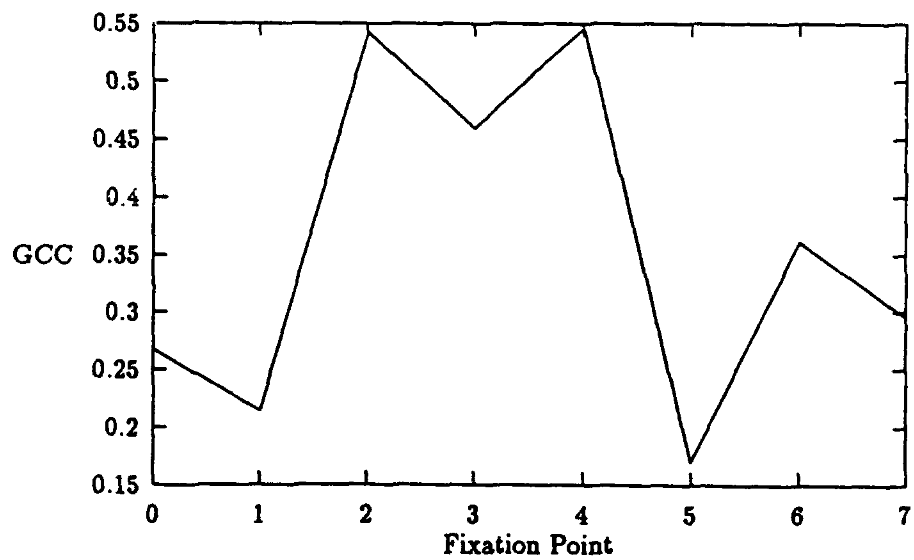

Figure 76. Plot of Subject K - New7 Image

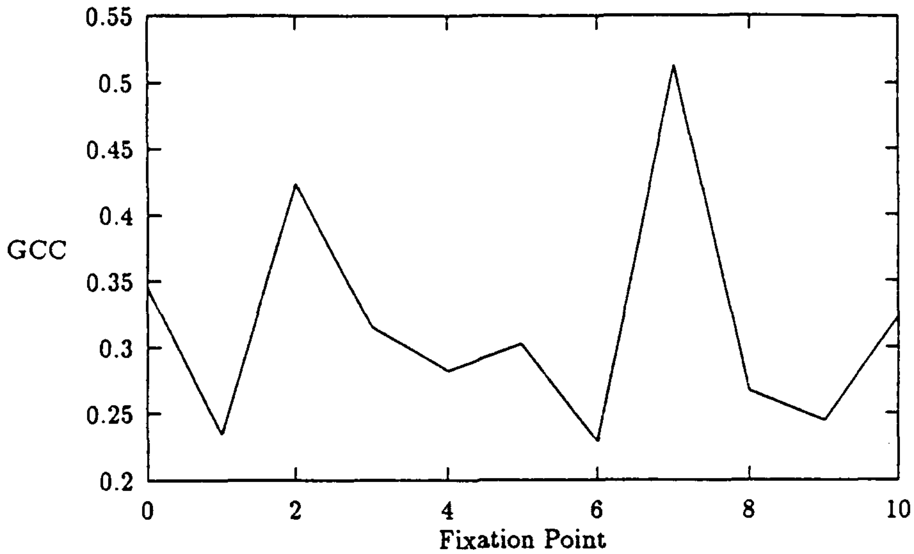

Figure 77. Plot of Subject S - New7 Image

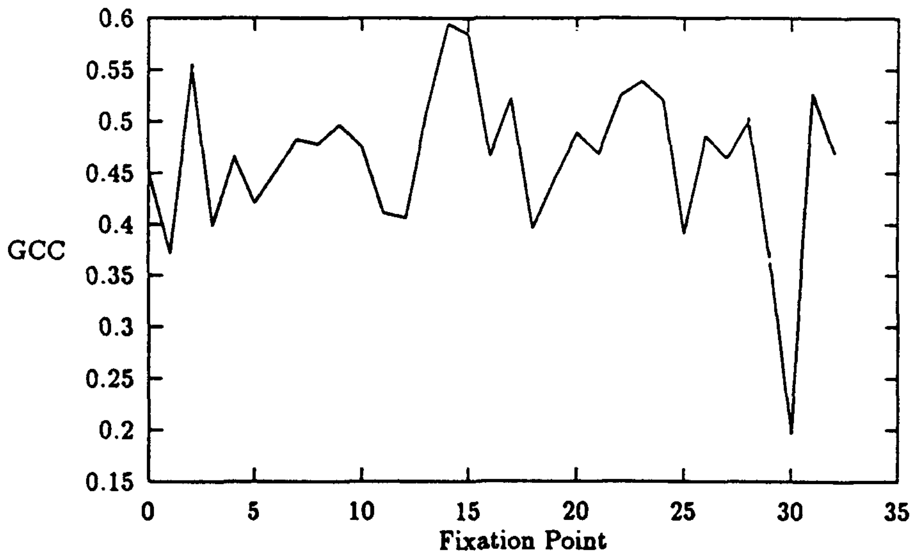

Figure 78. Plot of Average - New7 Image

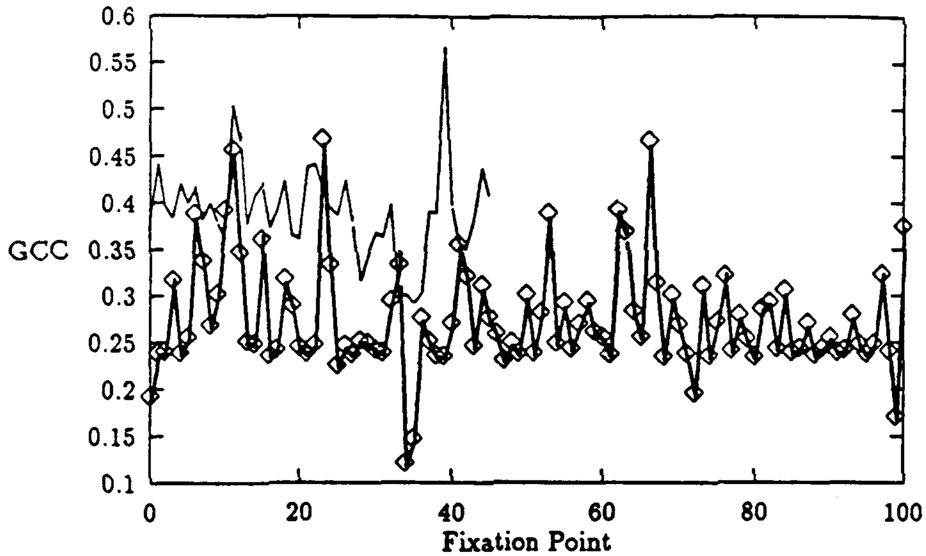

Figure 79. Plot of Average versus Baseline - Anna Image

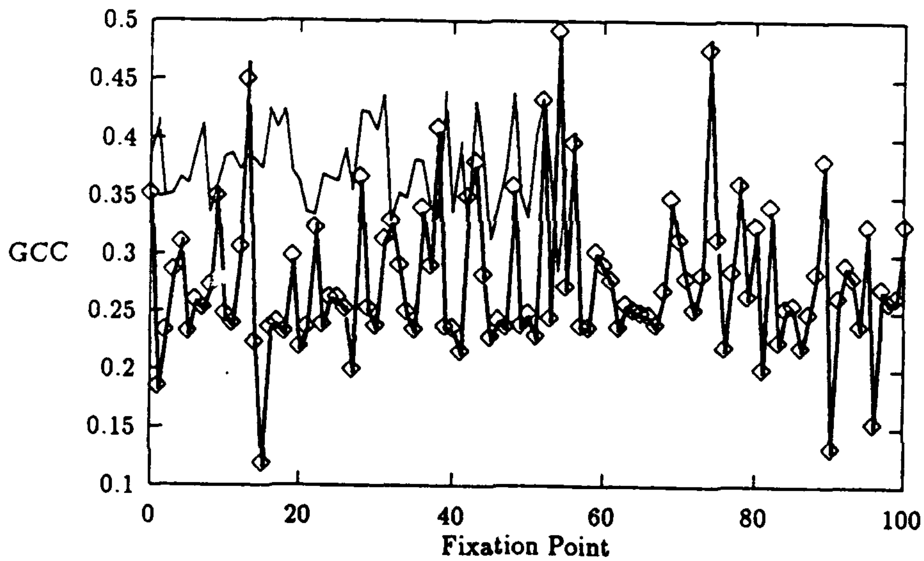

Figure 80. Plot of Average versus Baseline - Mountain Image

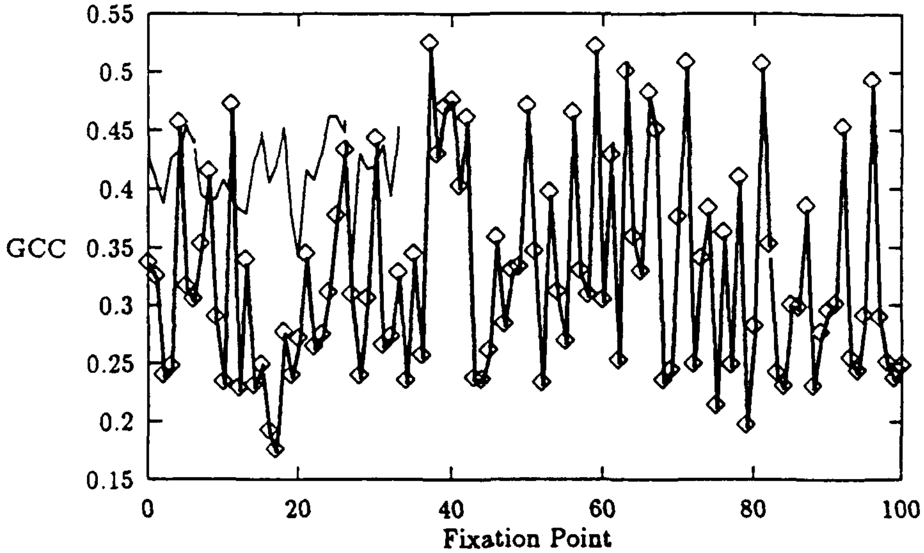

Figure 81. Plot of Average versus Baseline - Cobra Image

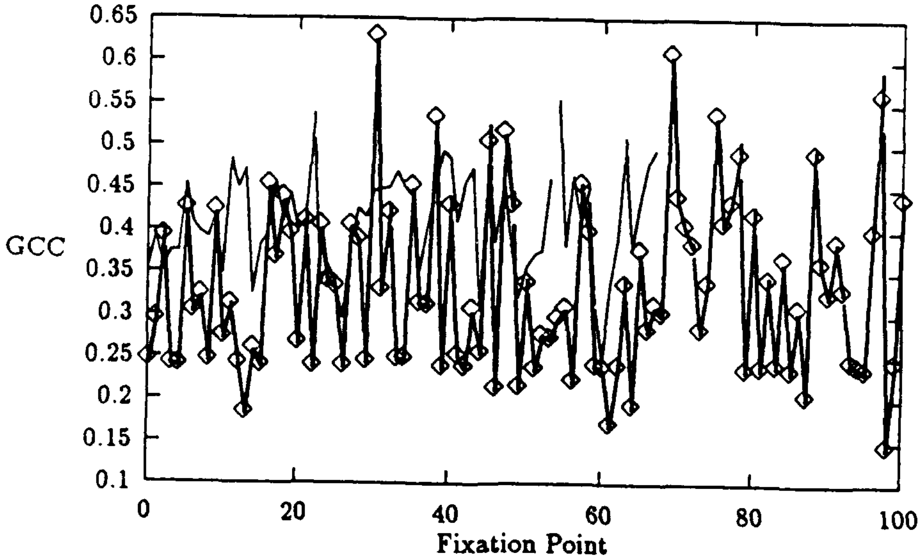

Figure 82. Plot of Average versus Baseline - New23 Image

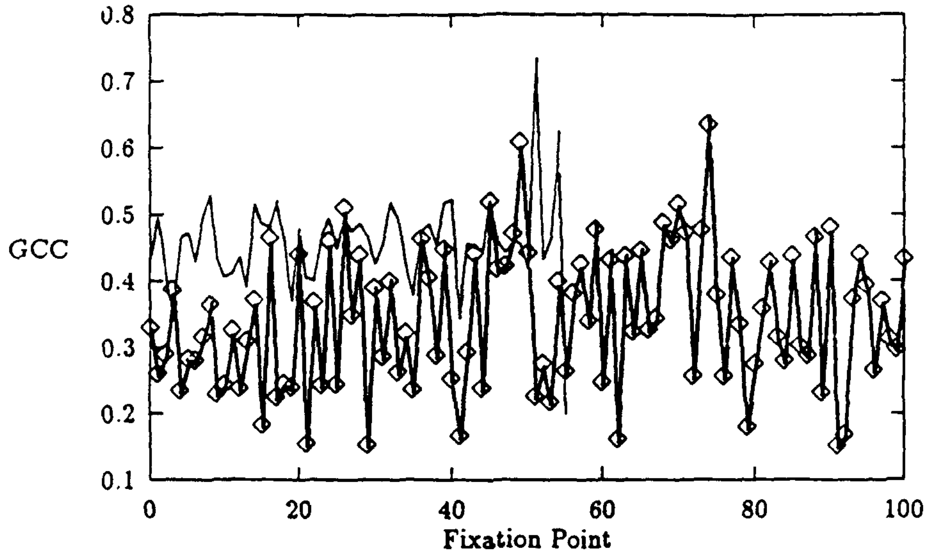

Figure 83. Plot of Average versus Baseline - Chipc1 Image

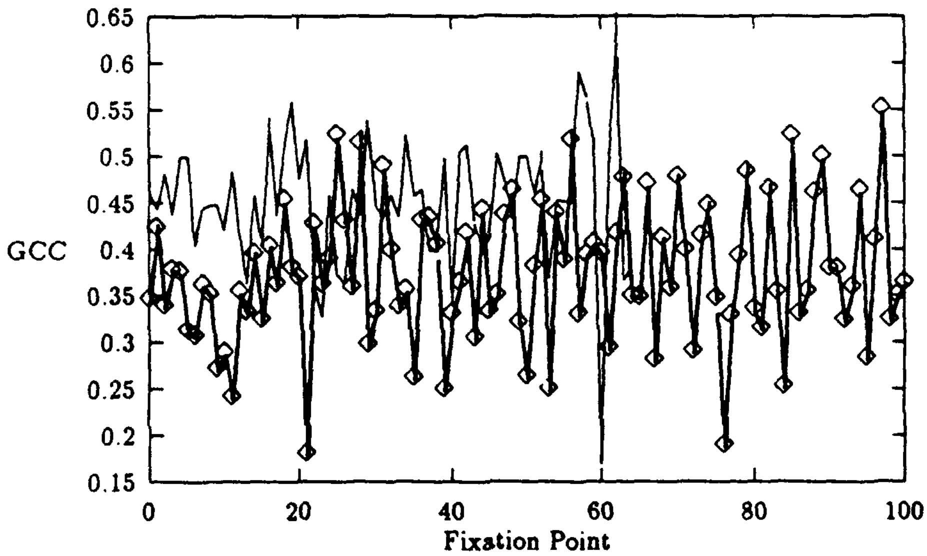

Figure 84. Plot of Average versus Baseline - Chipc2 Image

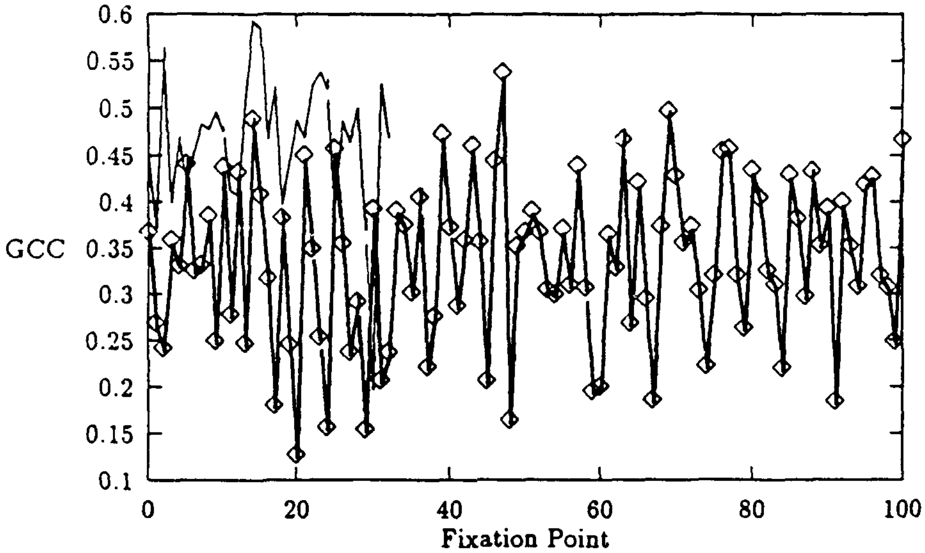

Figure 85. Plot of Average versus Baseline - New7 Image

Appendix B: *Verbal Cues to the Subjects*

The following are the verbal cues to the subjects for the images used in the data analysis for this thesis.

Anna Image - Describe what you see.

Mountain Image - Describe the contents of the scene.

Cobra Image - What is the unusual feature in this scene?

New23 Image - Why would these people be hesitant to carry out their apparent task?

Chipc1 Image - How many contacts are in this circuit?

Chipc2 Image - Count aloud all 9 contacts in this scene.

New7 Image - Are the horizontal wires electrically connected to the vertical wires?

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This thesis investigated whether a relationship exists between the Gabor Correlation Coefficient (GCC) magnitudes of fixation points for a set of images viewed by six subjects and the human visual search strategy. A couple of different relationships were investigated. First, the data were analyzed to determine if the GCC magnitudes of human fixation points predicted the time ordered sequence of human fixation points during the performance of a visual search. Second, the data were analyzed to determine if there was a significant difference between the GCC magnitudes of the human fixation points and the GCC magnitudes of a random set of fixation points. Finally, the data were analyzed to ascertain whether there was a difference between the GCC magnitudes of the fixation points at the beginning of the visual search and the GCC magnitudes of the fixation points at the end of the visual search.

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