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The stability of the iris as a biometric modality

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ABSTRACT

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In this thesis, the question of the stability of a group of individual subjects' irises is examined and answered. This stability is examined in regards to the time scale of the month range. The covariate for this research was time. Images collected during one month of separation between captures were examined. The genuine and impostor scores for these images were calculated and then interpreted using the stability score index. This index produced a quantifiable value for the stability of iris match scores over the months of the examination.

Additionally, a new framework for collecting and analyzing time in biometrics was created called the biometric time model. This model, which examines inputs from the smallest of phases (subject interactions with a sensor) to the life of the system or user provides detail of user and system metrics that were before unascertainable. With this model, a better understanding of how system and user data that was collected in different time intervals relates. Finally, a proposed method of the consistent language of reporting time in future research is produced.

CHAPTER 1. INTRODUCTION

Biometrics, “a measurable, physical characteristic or biological characteristic used to recognize the identity or verify these claimed identity of an enrollee” (Association of Biometrics, 1999, p. 2), rests on the pivotal concept that information gathered from a subject remains stable over time. A biometric can be defined as stable if the measurable characteristics of the subject are robust to change. There has been limited work done on the stability of biometrics with regards to iris recognition. Prior work has primarily focused on the effect of aging on biometric templates. For example, Baker et al. found “clear and consistent evidence of a template aging effect for iris biometrics” (2013, p. 215). However, Grother et al. found a slight change in iris performance, but determined that iris dilation effects were the primary cause of this change (2013, p. 49).

A US Department of Health and Education report in 1973 defined eight qualities which make up the perfect standard universal identifier (SUI) (Wayman, 2008). These qualities are uniqueness, permanence, ubiquity, availability, indispensability, arbitrariness, brevity, and reliability. Uniqueness, permanence, ubiquity, availability, and reliability are required for a universally implemented system to communicate with an SUI. Arbitrariness and reliability protect any information that may be contained within the SUI. Finally, indispensability requires that an individual must report their SUI correctly when asked. Biometrics follows many of these same desirable traits. These traits are universality, uniqueness, permanence, and collectability (Prabhakar et al., 2003). Permanence for both SUI and biometrics states that the feature being measured "must not change during an individual's life" (Wayman, 2008, p. 34). Namely, SUI and biometric modalities should remain stable over time.

Therefore, it is fundamental to the field to establish just how stable these modalities are, specifically with iris recognition. Since the development of the modality, the iris has been defined as "stable over time" (Daugman, 2004, p. 1). Over time, the iris has proven to be a usable modality when deployed to operational settings with mixed success. However, the question remains, mathematically speaking is the iris stable? This research aims to answer that question.

This chapter is comprised of the statement of the problem, research question, significance of the problem, scope of the study, definitions of key terms, assumptions, limitations, and delimitations.

1.1 Statement of the Problem

In order to create a more robust biometric system, additional research must be performed to establish if user stability is constant, specifically within the realm of iris recognition. Researchers have stated that the iris is "well protected from the environment and stable over time" (Daugman, 2004, p. 1). Stability can have two meanings in this connotation: physical and mathematical. Mathematical stability refers to the stability of metrics in biometrics such as match scores or quality scores. In order to solve this information gap, research must be conducted to identify the stability of user match scores. Establishing the stability of the iris could lead to new methodologies in user enrollment and identification.

1.2 Research Question

There is a singular problem this research hopes to answer: What is the stability of user match scores in an iris biometric system over the course of several months?

1.3 Significance of the Problem

Worldwide implementation of biometric entry access control systems is becoming more prevalent. Research must be conducted to determine how user performance changes over time. The greatest strength of the iris modality is that "as an internal (yet externally visible) organ of the eye, the iris is well protected from the environment. . ." (Daugman, 2004, p. 1). The stability of the iris has yet to be quantified; it has always been assumed. While stability within the realm of aging has been examined (Baker et al., 2013) and continues to be a point of discussion, no research to date has been conducted to determine if the match scores of the iris are stable.

Knowing if user match scores change over time can lead to several new research opportunities. For example, if match scores improve over time, matching algorithms can be set to be more permitting during early attempts and more stringent on later attempts. Adjusting algorithms will keep false non-matches low in the beginning while maintaining security and even improving over the lifespan of the system. Alternatively, certain individuals could change drastically while others do not. If this were the case, these users could be identified and held to a different acceptance threshold than those who are consistent. If very little change is present, the theory of the iris being stable over time is accepted and, therefore, the previous assumptions of the iris stability will be valid.

1.4 Scope of the Study

The purpose of this research is to establish the stability score, or the resiliency of an individual's match scores to change, for a user's iris genuine and impostor scores over time. Data will come from a subset of a 2013 Purdue University International Center for Biometrics Research (ICBR) dataset. The purpose of the 2013 study was "to exploit previously collected data and use international collaboration with Canada (Bion Biometrics and Carleton University) to create a large-scale study of biometric permanence. This study will leverage data from other studies as a baseline, and collect recurring data from this group over a period of two years" (Elliott, 2014, p. 22). Modalities collected for this study included iris, face, and fingerprint. Only iris images are examined in this research.

1.5 Definitions of Key Terms

Biometric fusion: The combination of "multiple modalities. . ., multiple impressions. . ., multiple classifiers. . ., multiple sensors. . ., or multiple units. . ." to improve the overall performance of the system (Ross et al., 2009, p. 1).

Biometrics: "a measurable, physical characteristic or biological characteristic used to recognize the identity or verify these claimed identity of an enrollee" (Association of Biometrics, 1999, p. 2).

Chameleons: "Intuitively, chameleons always appear similar to others, receiving high match scores for all verifications. . . Chameleons rarely cause false rejects, but are likely to cause false accepts" (Yager & Dunstone, 2010, p. 222).

Detection error trade-off curve (DET curve): A "modified ROC curve that plots error rates on both axes (false positives on the x-axis and false negatives on the y-axis)" (ISO/IEC JTC 1 SC 37, 2005, p. 7).

Doves: "Doves are the best possible users in biometric systems. . . They are pure and recognizable, matching well against themselves and poorly against others" (Yager & Dunstone, 2010, p. 222).

Enrolled data: "Biometric images that are stored in the system at the enrollment stage for the purpose of being matched upon later" (Gorodnichy, 2009, p. 1).

Equal Error rate (EER): "The rate at which the false accept rate equals the false reject rate. The EER can be used to summarize the performance of a system, as it contains both false match and false non-match information" (Dunstone & Yager, 2009, p. 104).

Failure to acquire rate (FTA): "If an error occurs while acquiring the biometric sample during a verification or identification, it is known as a failure to acquire. The proportion of verification or identification attempts that fails, for this reason, is the failure to acquire rate (FTA)" (Dunstone & Yager, 2009, p.104.

False accept rate (FAR): "Probability that the system incorrectly declares a subject a successful match between the input pattern and a non-matching pattern in the database" (Bhattacharyya et al., 2009, p. 22).

False match rate (FMR): The "proportion of zero-effort impostor sample features falsely declared to match the compared non-self" (ISO/IEC JTC 1 SC 37, 2005, p. 5).

False non-match rate (FNMR): The "proportion of genuine attempt sample features falsely declared not to match the template of the same characteristic from the same user supplying the sample" (ISO/IEC JTC 1 SC 37, 2005, p. 5).

False reject rate (FRR): "The probability that the system incorrectly declares failure of match between the input pattern and the template in the database" (Bhattacharyya et al., 2009, p. 22).

FRatio: Used to determine "the class-separability between the genuine and impostor score distribution of the user" (Ross et al., 2009, p. 3).

Genuine attempt: A "single good-faith attempt by a user to match their own stored template" (ISO/IEC JTC 1 SC 37, 2005, p. 2).

Genuine match: A match between two instances of the same biometric characteristic from the same person (Dunstone & Yager, 2009, p. 101).

Goats: Goat is a Doddington classification of individuals whose characteristics are particularly difficult to recognize (Doddington et al., 1998).

Impostor attempt: An "attempt of an individual to match the stored template of a different individual by presenting a simulated or reproduced biometric sample or by intentionally modifying his/her own biometric characteristics" (ISO/IEC JTC 1 SC 37, 2005, p. 3).

Impostor match: "A match between two different biometric characteristics. This is usually a match between two different people, but also includes a match between two different characteristics of the same person, such as matching left iris against the right iris" (Dunstone & Yager, 2009, p. 101).

Lambs: Lamb is a Doddington classification of individuals whose characteristics are particularly easy to imitate (Doddington et al., 1998).

Matching score: "Measure of the similarity between features derived from a sample and a stored template or a measure of how well these features fit a user's reference model" (ISO/IEC JTC 1 SC 37, 2005, p. 2).

Phantoms: "Phantoms lead to low match scores regardless of who they are being matched against; themselves or others" (Yager & Dunstone, 2010, p. 222).

Receiver operating characteristic curve (ROC curve): A "plot of the rate of 'false positives' (i.e., impostor attempts accepted) on the x-axis against the corresponding rate of 'true positives'" (ISO/IEC JTC 1 SC 37, 2005, p. 6).

Sample: A "users biometric measures as output by the data collection subsystem" (ISO/IEC JTC 1 SC 37, 2005, p. 1).

Sheep: Sheep is a Doddington classification of individuals who perform normally and dominate the population (Doddington et al., 1998).

Template: A "users stored reference measure based on features extracted from enrollment samples" (ISO/IEC JTC 1 SC 37, 2005, p. 2).

User: The "person presenting the biometric sample to the system" (ISO/IEC JTC 1 SC 37, 2005, p. 3).

Verification: The "application in which the user makes a positive claim to an identity, features derived from the submitted sample biometric measure are compared to the enrollment template for the claimed identity, and an accept or reject decision regarding the identity claim is returned" (ISO/IEC JTC 1 SC 37, 2005, p. 4).

Wolves: "Wolves, in our model, are those speakers who are particularly successful at imitating other speakers…Wolves tend to adversely affect the performance of systems by accounting for a disproportionate share of the false alarms" (Yager & Dunstone, 2007, p. 1).

Worms: "Worms are the worst conceivable users of a biometric system… If present, worms are the cause of a disproportionate number of a system's errors" (Yager & Dunstone, 2010, p. 222).

1.6 Assumptions

The assumptions of the project include:

1. Subjects did not intentionally interfere or adversely affect the data collection process and made an honest attempt when interacting with the sensor.
2. All collection processes were followed correctly by subjects and test administrators.
3. There was no altering or degradation of stored images.
4. All hardware and software functioned properly at the point of collection.

1.7 Limitations

The project was limited by the following:

1. The findings of this study are limited to iris images collected from the 2013 Purdue University International Center for Biometric Research (ICBR) dataset.
2. Collection methods were established by other protocols and may not have represented the perfect collection conditions for this study.
3. Image collection was conducted in a laboratory environment at a single research facility at Purdue University in West Lafayette, IN.

1.8 Delimitations

The project was delimited by the following:

1. Only one iris capture device and one matcher were used in this study.
2. Other modalities such as fingerprint, face, palm, or physiological modalities were outside the scope of this research.
3. Three images were randomly selected for each subject per visit to create each datarun.

1.9 Chapter Summary

In this chapter, the foundation and framework for the rest of the study was established. The iris modality has been defined as stable, but there has not been a distinction between physiological stability and match score stability. This research will examine the stability of the match scores across a range of visits approximately one month apart.

CHAPTER 2. REVIEW OF THE LITERATURE

This study will examine user stability scores over monthly intervals within the iris modality. This chapter will cover five sections: an introduction to biometrics, an overview of iris recognition fundamentals, performance evaluation methods, the biometric zoo menagerie, and stability scores. The purpose of this chapter is to establish a background of the current research and methods for establishing stability of the iris.

2.1 Introduction to Biometrics

Human beings are innately proficient at recognizing and identifying other human beings. People are capable of looking at images and identifying the faces of loved ones, friends, colleagues, and even people they have never met such as professional athletes or celebrities. In some cases, people are capable of identifying those they have very close connections to such as parents and siblings in baby pictures. It is difficult to duplicate this innate human skill on a machine with algorithms and hardware.

Researchers have developed three ways to assign an identity. One is to assign specific knowledge to only one individual so they can reproduce this knowledge for identification purposes. An example would be using a password to sign into an email account or to input a pin number to access an automated teller machine (ATM). The second way to assign an identity is to give the individual a token of that an they present as identification. An example would be showing a state issued identification card to vote in an election. The last way to assign an identity is by analyzing a physical feature of an individual, storing that information, and reanalyzing that feature at a later time for identification, which is better known as biometrics.

"Biometrics is an automated technique of measuring a physical characteristic of a person for the purpose of recognizing him/her" (Gorodnichy, 2009, p. 1). It is important to analyze and define each term in this statement. The word 'automated' is crucial, as a pure biometrics system should have as little operator interaction as possible. 'Physical characteristics' refers to physical traits that the average human possesses such as fingerprints, irises, facial features, and veins. In the case of this definition, it also applies to behavioral biometrics, which can include but are not limited to signature patterns and vocal characteristics. Furthermore, the entire purpose of this process is to 'recognize' an individual, not just gather surveillance on them. Recognition is either performed as verification or identification. In verification, the user declares an identity by password or presents a token of some kind which activates protocol for the system to retrieve an enrolled template. The template is then matched to the current template that the subject presents to the sensor. Verification is a one-to-one match, meaning the user is matched only to a previously enrolled template and determines if the statement "I am whom I say I am" is factual. In identification, the user presents the required biometric feature to sensor. The sensor extracts this data, which is then compared it to every template enrolled in the system. Identification is used to answer the question "Who is this?"

There are multiple biometric modalities that are currently being researched and that are in use around the world. Some of these modalities include fingerprint, face, iris, hand geometry, retina, signature, hand vein, keystroke, and gait. Other, more unique modalities include thermal imaging, fingernail bed, and body odor (Bhattacharyya, 2009). Each of these modalities has differing strengths and weaknesses from both academic and deployment standpoints. For example, facial recognition is particularly useful for covert surveillance of large, busy areas, but tends to be expensive to develop and deploy. Conversely, hand geometry recognition must be performed with the cooperation of the individual, which makes it an overt collection process. However, it is fairly inexpensive to deploy and is well established as a biometric modality. An understanding of these strengths and weaknesses is critical when considering which modality to deploy for operation.

All modalities use a common framework for the biometric process called the general biometric model. Wayman (1998, p. 294) created the model to encompass the entire process of biometrics including "'identification' or 'verification', or 'operation' or 'enrollment'". The model consists of five phases: collection of the data, transmission of the data, signal processing, storage of the data, and the system making a decision to accept or deny the user. The data collection phase collects the raw data of the modality being used. "The biometric pattern is 'presented' to a sensor, which transduces the pattern into an electronic signal" (Wayman, 1999, p. 291). The electronic signal is transmitted to the processing center in the next phase. In order to accurately transmit this data, it must be compressed and then expanded, which may slightly alter or degrade the original information. The next phase, signal processing, takes the uncompressed information of the original biometric pattern and converts it into a form the particular matching algorithm can use for either enrollment or operational purposes. For enrollment, the newly converted information is stored in the database; this is phase four, storage of the data. If the newly converted information is the used for matching, the model moves to the decision stage. The determination is made using a previously set matching threshold as to if the biometric pattern is accepted or rejected when compared to the stored pattern.

2.2 Iris Recognition

The iris is the colored portion of the eye surrounding the pupil. Its purpose is to control the light levels allowed inside of the eye. The processes that creates the iris begins when a fetus enters the third month of gestation with the majority of the structures that compose the iris reaching completion after the eighth month of pregnancy (Kronfeld, 1962). There are several significant strengths to mention when considering the iris as a biometric modality. First, the iris is an internal organ, yet can be accessed externally, which means it is fairly well protected from day to day wear and tear that other modalities such as fingerprint must accommodate. However, even though it is internal, the iris is readily accessible for data capture. Another strength is the staggering individual variation among iris patterns. There are 266 distinct characteristics of the iris with 173 of these features used in iris recognition (Khushk & Iqbal, 2005). Because of the number of features, this means that individual iris variation can be quite significant. This variation can be accurately measured, yielding excellent performance. In fact, Solayappan and Latifi (2006) found the error rate, or the rate at which a biometric system fails, for a variety of modalities. Iris had a score of 1 in 131,000, which is better than fingerprint recognition which had an error rate of 1 in 500+. As a matter of fact, iris performed better than all other modalities except for retinal scan technology (Solayappan & Latifi, 2006, p.

6). These factors make iris recognition a very attractive option when a large population requires a high level of security.

The original iris recognition algorithm was created by John Daugman in 1994 (Daugman, 2004). The process of iris recognition constitutes three main elements: image capture, iris location and image optimization, and storage and comparison of the image (Khaw, 2002). The image of the iris is captured by a camera using either visible light or infrared light and is performed one of two ways: either manually or automatically. The automatic process is the preferred method because the eye is automatically located. In the second stage, iris location and image optimization, the outer bounds of the iris (where the white sclera of the eye meets the iris) and the inner bounds (where the pupil and the iris meet) are located. The result is an exact location of the iris. The system removes any areas that would not be suitable for data extraction, i.e. eyelashes, dark areas, or reflective spots. The third and final stage, the storage and comparison of the image, involves several steps. First, the image is filtered into segments which isolate specific features. A multitude of algorithms are used to compensate for a number of variables including pupil size and angle of the image. This information is then converted into a "512-byte record" (Khaw, 2002, p. 8). Finally, this record is transferred to a database for comparison. The comparison software does not compare the image, but the 512-byte record that the algorithm created.

Daugman's model utilizes a comparison system called the Hamming Distance (HD). The HD is the "dissimilarity between any two irises" (Daugman, 2004, p. 23). The HD has its roots in the medical field, as it is used to ensure the proper dosage of medication is administered to a patient. The dissimilarity of the iris is measured by comparing a binary string known as phase bits, which are produced after image segmentation and outputs a similarity score equal to the percentage of digits that do not match. The score ranges from zero to one with zero being the best performance. Table 2.A shows an example HD calculation. This example only shows 20 phase bits instead of standard 512. The HD is compared to a previously set HD criterion. If the HD criterion is lower, the user is allowed access to the system. By altering the HD criterion even slightly, the false match rate, which is the rate that the system incorrectly matches an impostor user to a genuine template, decreases dramatically. For example, an HD criterion of 0.30 results in a false match rate of 1 in 1.5 billion. By increasing the HD criterion by just 0.01 to 0.29, yields a false match rate of 1 in 13 billion. That means that only 1 in 13 billion users will be incorrectly identified on average (Daugman, 2004, p. 27).

Table 2.A *HD Criterion Example*

	Phase Bits																				
Image Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Enrolled	1	0	0	1	0	1	1	0	0	1	1	0	0	1	0	1	0	1	0	1	
Time of Interaction	1	1	0	1	1	0	1	0	1	1	1	0	0	1	0	1	1	1	1	1	HD
Difference	0	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0.3

2.3 Performance Evaluation

In biometrics, there are several terms and definitions used to describe system performance. Biometric literature (Bhattacharyya, 2009; Dunstone & Yager, 2009) presents several methods for analyzing performance, three of which are illustrated. These are score histograms, the receiver operator characteristics (ROC) curve, and the detection error trade-off (DET) curve. These tools graphically show information about the tradeoff between false accept rate (FAR), false reject rate (FRR), false match rate (FMR), and false non-match rate (FNMR)

FMR, shown in Equation 2.1, is the proportion of impostor templates that are falsely admitted into the system under the guise of a genuine user. FNMR, shown in Equation 2.2, is the proportion of genuine users that are falsely branded as impostors. FAR, shown in Equation 2.3, denotes the probability that a system will falsely accept the incorrect user and allow them to access the system. FRR, shown in Equation 2.4, conversely, denotes the probability that a system falsely denies the proper user access to the system (Bhattacharyya, 2009). Selecting an appropriate FAR and FRR is a constant challenge that biometric developers must supervise closely in both development and operational settings. If the system has a high FAR, it makes the system insecure but makes the entry quicker and less complicated. If the system has a high FRR, the correct users may not be able to access the system. Under these circumstances, the system is secure but can be very aggravating to the user. Equal Error Rate (EER) is the point where FAR and FRR are equal.

$$\mathrm{FMR} = \frac{\text{Impostor attempts that that generate comparison score below the threshold}}{\text{Total impostor attempts}} \quad \text{(Eq 2.1)}$$

$$\mathrm{FNMR} = \frac{\text{Genuine attempts that generate comparison score below threshold}}{\text{Total genuine attempts}} \quad \text{(Eq 2.2)}$$

$$\text{FAR} = \text{FMR} * (1 - \text{FTA}) \qquad \text{(Eq 2.3)}$$

$$\text{FRR} = \text{FTA} + \text{FNMR} * (1 - \text{FTA}) \qquad \text{(Eq 2.4)}$$

2.3.1 Score Histograms

A score histogram is a graphical representation "of scores for non-match. . . and matches. . . over the match score range" (Dunstone & Yager, 2009, p. 20). For a system to operate properly, these two frequencies should have as little overlap as possible. If the two are overlapping, the users in that score range may either result in a FAR or FRR. If they do not overlap, the system can accurately determine which users should be allowed into the system and which should not. The primary strength of the score histogram is that it displays the data graphically in order to understand the system operation better and to establish system thresholds. Figure 2.1 is an example of this. The software does not output vertical bars to indicate data points, but instead uses a pair of lines. The dotted line represents the impostor scores, and the solid line represents the genuine scores. In this example, impostor and genuine scores are overlapping. Users who yield a genuine or impostor score that are located in the overlapping range may be either as a genuine user or impostor user. A clear distinction between genuine lines and impostor lines is most desirable so a genuine and impostor users can be readily distinguished from one another. However, this is not always the case.

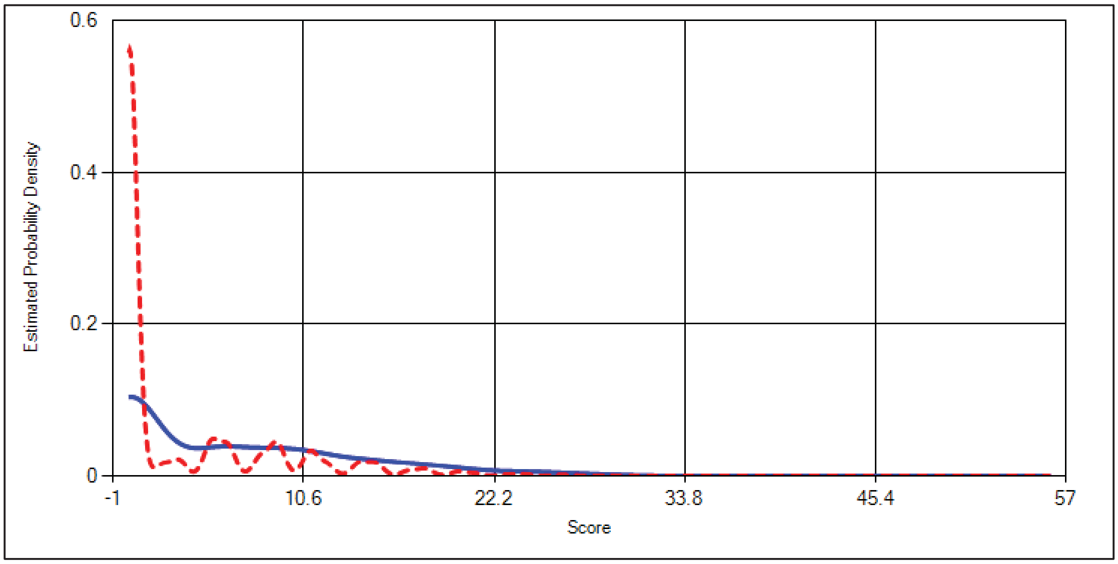

Figure 2.1 Histogram Example

2.3.2 Receiver Operating Characteristics (ROC) Curves

A receiver operating characteristic (ROC) curve "is obtained by graphing the values of FAR and FRR, changing the variables implicitly" (Bhattacharyya, 2009, p. 22). A graphical representation of the FAR and FRR shows the tradeoff between correctly verifying an individual versus producing a false match. The verification rate is equal to 100 – FNMR and is the probability of correctly allowing a genuine user to access the system. In most cases, the x-axis (false match rate) is a logarithmic function that shows operating thresholds at drastically different verification rates. The true acceptance rate (TAR), which is equal to 1-FAR, can also be displayed on the x-axis. Figure 2.2 is an example of a ROC curve. ROC curves were also created for the medical field in order to administer proper medication dosage. The strength of the ROC curve allows system administrators to find the best operating conditions with the lowest acceptable FAR to solve the problem about how to create a system that accepts the right individuals quickly but keeps the impostors out. It is also useful when comparing the performance of one system to another.

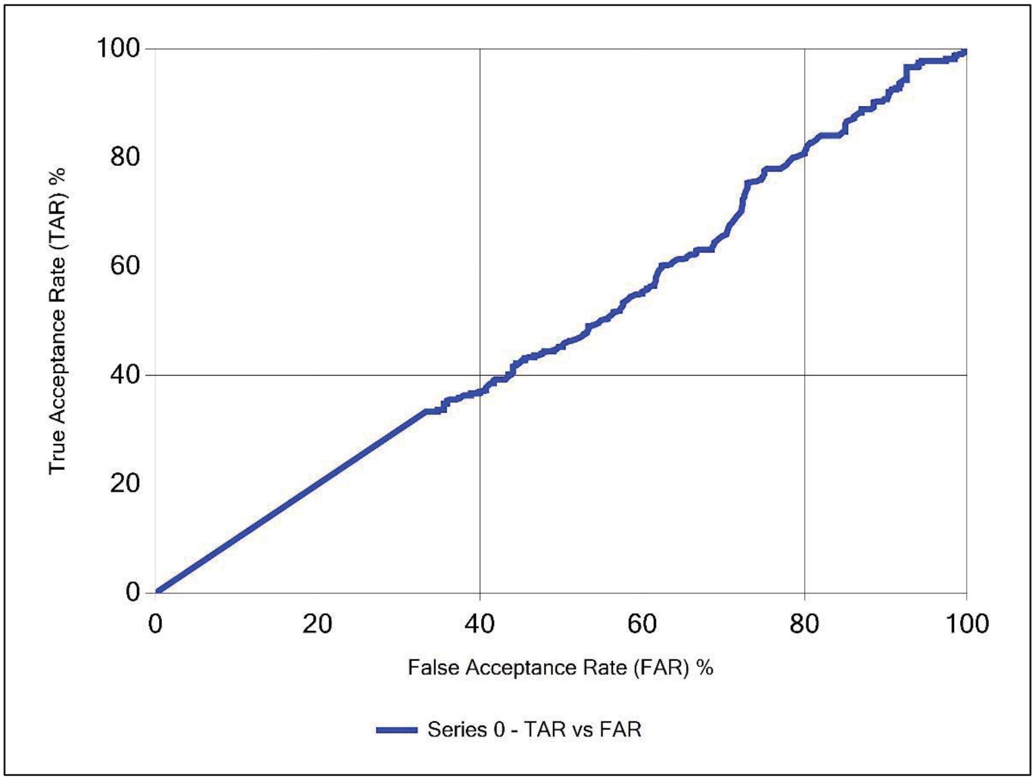

Figure 2.2 ROC Curve Example

2.3.3 Detection Error Trade –off (DET) Curves

Detection Error Trade-off (DET) curves are quite similar to ROC curves with the exception that the x and y-axis are displayed as a logarithmic function. As with the ROC curve, the variables are represented on a logarithmic scale which allows for the presentation of "performance results where tradeoffs of two error types are involved" (Martin et al., 1997, p. 4).

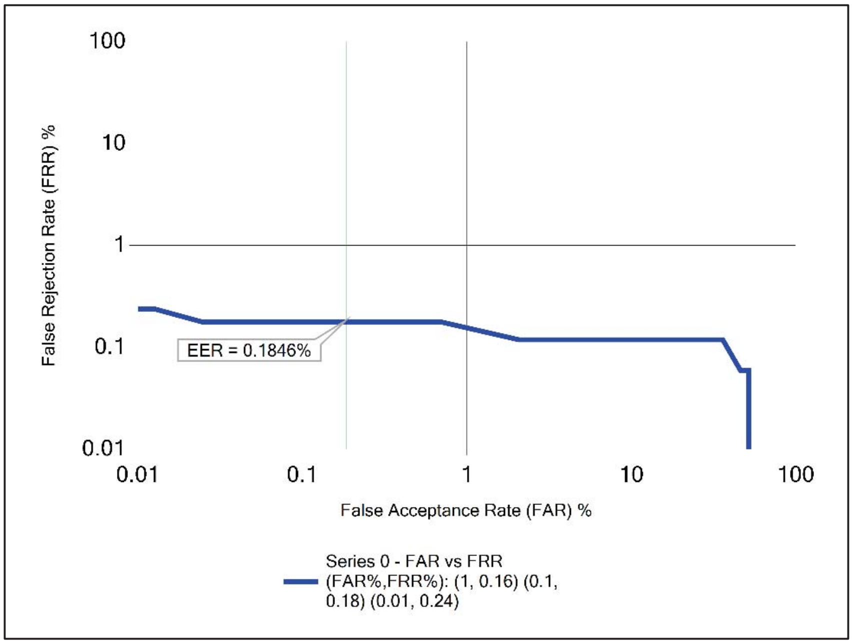

Figure 2.3 DET Curve Example

2.4 The Biometric Zoo Menagerie

While receiver operating characteristic (ROC) curves and detection error trade-off (DET) curves represent the performance of the whole system, they are not capable of showing individual performance in relation to the sample. "This weakness is important because the curves may not provide the whole story; the data cannot be fully interpreted" (O'Connor, 2013, p. 15). The biometric zoo menagerie was created to fill this information void. It allowed data to be analyzed on an individual basis: poor and excellent performing subjects alike can be identified and these subjects' features studied. An image that is distinctly verified to itself will have a high genuine score and a low impostor score. Conversely, an impostor score is the result of a ground-truth, verified non-match to an existing template. An image that is distinctly verified to another image belonging to a different user will have a low genuine score and a high impostor score.

2.4.1 The Development of the Zoo Menagerie

Doddington et al. first proposed the theory of classifying user match scores into distinct classes in a National Institute of Standards and Technology (NIST) sponsored evaluation of speaker recognition (1998). The authors proposed four distinct zoo classifications: Sheep, Goats, Lambs, and Wolves. These animal classes are found using genuine match scores. The genuine match score is the score that the matching algorithm outputs that mathematically assures the subject is a genuine user. Sheep represent the standard speaker and are characterized by high genuine scores. Most users fall into this classification. Goats are users who tend to be difficult to match, either to themselves or others, and are the common source of false rejects. Goat scores represent the bottom 2.5 percentile of average scores. Lambs are those users whose characteristics are inherently easy to mimic. Wolves are those users who tend to be more successful at emulating other user templates and encompass user match scores in the top 97.5 percentile. Lambs and Wolves are directly related: a Lamb cannot exist without a Wolf. They are the direct causes of false accepts.

The biometric menagerie has also been proven to exist in other modalities aside from voice. Wayman validated the existence of wolves and lambs in fingerprint recognition and also discovered an interesting observation (2000). Sheep and wolves exist but not in distinct groups. Evidence “shows both lamb and wolf distributions to be smoothly spread” (Wayman, 2000, p. 186). Additionally, Wittman et al. demonstrated in a later study that the zoo menagerie could also be applied to face recognition (2006). The researchers examined the impact of facial expressions and lighting on performance and matching ability of the individual. Results showed that these factors played a role in classifications changes depending on which animal class the user is classified.

Yager and Dunstone expanded the zoo menagerie by creating different animal classes with more robust classifications (2007). The new animal classifications (chameleons, phantoms, doves, and worms) use not only genuine scores (G_k), but also impostor scores (I_k) to define their characteristics. The impostor score is a score that the matching algorithm outputs which mathematically states the assurance that the subject is not a genuine user. Scores are first segmented into interquartile ranges for G_k and I_k. All scores from the sample are placed on an X-Y chart with average genuine scores comprising the X axis and the average impostor scores comprising the Y axis (Figure 2.4). The animal classes and characteristics are:

Chameleons – Represents the subjects with both high G_k and high I_k. They are the primary source of false accepts and are unlikely to cause false rejects. These users tend to have very generic features. This animal class is located in the bottom right of the plot.

Phantoms – Represents the subjects with both low G_k and low I_k. They are the primary source of false rejects and are unlikely to cause false accepts. These users tend to have trouble enrolling and, therefore, have poor quality base images. This animal class is located in the top left of the plot.

Doves – Represents the subjects with high G_k and low I_k. They are the best possible subjects, matching very well to themselves and not very well to others. These users tend to have very distinct physical features, setting themselves apart. This animal class is located in the top right of the plot.

Worms – Represents the subjects with low G_k and high I_k scores. They are the worst possible subjects. Multiple worms can have a catastrophic impact on the system and may be an indicator of serious fundamental system flaws. Users in this classification are at the most risk from impostor attempts. This animal class is located in the bottom left of the plot.

Normal – These users represent the majority of the population. They perform within acceptable standards for the system to function. They fall in between the bounds of the other classification ranges.

Not only did Yager and Dunstone establish the existence of these new animal classifications, they also proposed three causes for the formation of the zoo (2007). The first is algorithm weakness. This theory states that if the matching algorithm has bugs or errors, the sample may have an inordinate amount of poor performing classifications, the most notable being worms. The second is poor enrollment quality. A large proportion of phantoms is an indicator of poor data capture at the enrollment phase. Finally, data integrity may be a weakness. Users tend to be classified as phantoms or chameleons for mistakes such as multiple enrollments, enrollment fraud, or ground-truth errors.

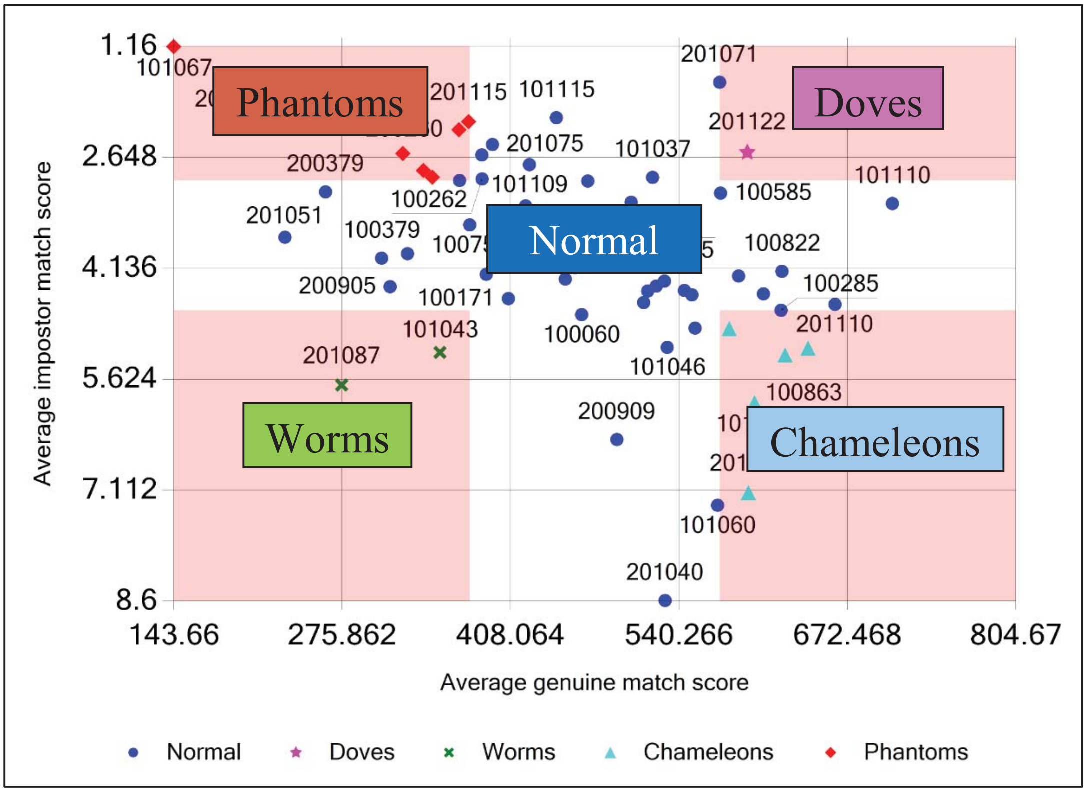

Figure 2.4 Zoo Menagerie Example 1

Yager and Dunstone went on to establish the new zoo menagerie for a multitude of modalities, including fingerprint, iris, two dimensional face, speech, three dimensional face, and keystroke analysis (2010). Of the 208 subjects, only seven were identified as worms or doves (Yager & Dunstone, 2010). Additionally, there were an inordinate number of phantoms. Upon further analysis, many of these individuals were found to be wearing glasses, which supports the theory that the zoo menagerie exists because of poor quality enrollment capture. There were several conclusions that came from this work. The first being that there are many reasons for the menagerie existence. These reasons are a complicated, intricate problems. Some reasons include algorithm robustness, data quality, enrollment processes, feature extraction, and properties that may exist within the population. Another conclusion was that there are inherently difficult people within the population that cannot enroll into a biometric system. Previous research by Hicklin et al. concluded that there are very few users who had fingerprints that are inherently impossible to match (2005). Of the 6000 subjects in their study, less the 0.2% had fingers that were hard to match 25% of the time (Hicklin & Ulery, 2005).

A third form of a zoo menagerie moves away from using genuine and impostor scores and instead uses image-specific error based on a threshold that was created by Tabassi (2010). In this case, images are categorized instead of the subject. The images are classified into four classifications: clear ice, black ice, blue goats, and blue wolves. These classifications are plotted an X-Y chart very similar to Dunstone and Yager's classification. Clear ice images are images in which the false non-match rate is less than the minimal false match rate. Like phantoms, these users are located in the lower left of the plot. Black ice are comprised of users who match well with others, as well as the original user. These images are similar to their subject counterparts, chameleons, and occupy the top right of the plot. Blue goats, like worms, are the poorest performing images and occupy the top left of the plot. Finally, blue wolves are images that perform better than all others and occupy the bottom right. They are comparable to doves in the Yager and Dunstone model. This study discovered that in using a different metric to measure performance, different information about the same subject can be learned. The most interesting aspect of this discovery is that there may be more factors at work in regards to the image causing errors. The primary strength of this classification method is that "it can be used to assess the comparison algorithm robustness to image quality variation" (Tabassi, 2010, p. 1126).

2.4.2 Zoo Menagerie Weaknesses

Zoo plots are not without critics (Popescu-Bodorin et al., 2012; Shuckers, 2010). According to Shuckers, "in terms of the evaluation of biometric system performance, there is not a need to consider the 'Zoo'" (2010, p. 300). The zoo menagerie should not be regarded as a biometric performance metric because the data being used is historical. He goes on to say:

> The open research question that has not been empirically resolved is the existence of the 'Zoo' in the first place. In particular, is an individual a 'goat' for all systems of a particular modality? Do we have universality of animal type? Put another way, does the characterization of an individual as a particular type of animal depend solely on that individual or does it depend upon other elements of the matching process such as environmental factors or whether the fingerprint reader is touchless. Further, this area of research is in need of some explicit definitions of what makes someone a 'goat' or a 'sheep' or a 'wolf'. Having mathematically rigorous definitions would allow for the creation of testable hypotheses regarding these characterizations (Shuckers, 2010, p. 300).

Popescu-Bodorin et al. adds to the list of criticisms of the zoo menagerie within the iris modality (2012). The first issue addressed with the menagerie is that the concept of categorically classifying users, which may lead to unfounded correlation assumptions. Instead, biometric data should be classified by the particular modality biometric template (iris codes, for example). The next issue is that previous literature does not adequately define the terms of numerical interpretations the zoo classifications. "The Biometric Menagerie is rather dependent on the calibration of the biometric system that being objective concept. . . " (Popescu-Bodorin et al., 2012, p. 2). Another issue discussed is the idea that some users may just "win the lottery" (Popescu-Bodorin et al., 2012, p. 3). The idea that users may win the lottery is that according to chance, some users will eventually display different animal characteristics. Wolves can be the winners of this fictitious lottery. It is not the features of the wolves that bring them together in one class; it is simply pure chance. The authors summarize the findings of their research as follows:

> By illustrating the fact that, different iris recognition systems actually perceive differently the wolf- and goat-templates, the current paper qualifies the concept of Biometric Menagerie as not having one of the most important and most needed attribute of a concept, namely the universality with respect to a genus (Popescu-Bodorin et al., 2012, p. 8).

2.4.3 Zoo Menagerie Applied

Studies have identified how the biometric menagerie can be implemented in other areas of biometric research. Biometric fusion is the combination of some aspect of retrieved data with some other retrieved data to produce a result better than either individual data source. An example of fusion includes the combination of genuine and impostor scores, image templates, or as Ross et al. (2009) proposed, by using a multibiometric system in order to increase throughput. A multibiometric system for fusion is accomplished by using either user-specific fusion or user-specific selection. In user-specific fusion, all users are pre-enrolled into the system with one particular modality. Administrators then identify weak users using the Doddington et al. menagerie and the FRatio (used to calculate the class-separability between the impostor and genuine scores) and then enrolls a second modality for these particular users. These methods are very useful because they save time and money from enrolling all users into two modalities when some of the population may enroll in one for accurate identification and perform within acceptable limits.

User specific selection is the second biometric fusion method using the zoo menagerie. In this case, all users have been enrolled into a system with two modalities. If when the user interacts with the system for the first modality, and they are classified as a sheep, they can move on. If the first modality does not perform well, the second modality information is gathered, and both will be considered for the accept or deny decision. This approach uses the Doddington et al. animals and the FRatio (Equation 2.5). This scheme allows for quicker throughput and a more efficient data exchange and storage process in systems that already have two modalities stored. The FRatio is used to measure the ratio of variance between groups to the variance within those groups. Essentially, the FRatio is the ratio of the explained variance to unexplained variance. For computing the FRatio, "μ_c and μ_I are the mean genuine and impostor score, respectively, while σ_c and σ_I are the variance of the genuine and impostor scores, respectively, of a single user" (Ross et al., 2009, pg. 3).

$$\text{FRatio} = \frac{\mu_c - \mu_I}{\sigma_c - \sigma_I} \qquad \text{(Eq 2.5)}$$

Paone and Flynn examined biometric menagerie consistency across three different verification algorithms using both eyes (2011). The three verification algorithms were used to produce the respective match scores from the commercially available Iris Challenge Evaluation (ICE) dataset. Both the Doddington et al. menagerie and Yager and Dunstone menagerie were used for the three algorithms. The all-pairs matching comparison yielded that menagerie classifications are dependent on the algorithm being used. Additionally, when the researchers looked to find a correlation between left iris and the right iris classification, none was found. Almost all subjects were considered to be weak by only one matching algorithm in one eye. Therefore, no subjects could be deemed to be inherently weak with any measure of confidence. The final determination was made that the menagerie classifications could still be applied, but only when the same matching algorithm used on one eye. “The benefits of the biometric menagerie can still be attained if care is taken to ensure that the subject’s classifications are representative of the dataset chosen” (Paone & Flynn, 2011, p. 6). These issues bring into question the interoperability of iris sensors and matching algorithms.

2.5 Stability Score Index

Previous research conducted by O’Connor (2013) set about to answer the question “Is an individual’s performance unstable with regards to the covariate under study in a fingerprint recognition system?” (O’Connor, 2013, p. 3) In this work, O’Connor developed a method of measuring the stability score of an individual by outputting a stability score index (SSI). The SSI allows for a better understanding of how much a user score shifts and changes across two different interactions. “The stability score gives algorithm developers insight into particular users who perform poorly or exceptionally well in a particular dataset" (O'Connor, 2013).

The SSI can be found in Equation 2.6 (O'Connor, 2013, p. 52). Each individual (i) is analyzed alone from the sample. x_1 and x_2 represent the genuine score of the initial position of the data point in question and the position of the second data point respectively. y_1 and y_2 represent the impostor score of the first position and subsequent position respectively. x_{max} and y_{max} represent the maximum genuine and impostor score respectively across all intervals for all users. x_{min} and y_{min} represent the minimum genuine and impostor score respectively across all intervals for all users. SSI outputs an analysis on a scale of zero to one. Zero signifies that the user is perfectly stable across the two intervals being studied. One, conversely, signifies the maximum possible movement by the user between the two interactions in question.

$$S.S.I. = \frac{\sqrt{(x_{i_2}-x_{i_1})^2+(y_{i_2}-y_{i_1})^2}}{\sqrt{(x_{max}-x_{min})^2+(y_{max}-y_{min})^2}} \qquad \text{(Eq 2.6)}$$

O'Connor's primary goal was to analyze the movement of users across different force levels (5N, 7N, 9N, 11N, 13N) and then investigate particular subjects of interest (2013). Four subjects were isolated for further study. These four subjects showed significant intraclass and interclass variation. The SSI of a subject that exhibited the intraclass variation, more specifically stayed within normal class, when comparing match scores from 5N and 7N was calculated to 0.3512 (O'Connor, 2013). These findings show that, even though, this particular user had the same classification (normal) under both force levels, these two scores are quite different from each other. Users were so unstable that they even jumped classifications. An example of an interclass variation, or a change in zoo classification, is subject 117 (O'Connor, 2013). This subject was classified as a dove at the force level 9N but was then classified as a phantom at the force level 11N. As expected, this individual displayed a large SSI at 0.5537. However, small stability scores can still have an impact on user performance. Subject 178 had an SSI of 0.0308 but was enough to change classifications from a phantom at force level 7N to a normal classification at 9N (O'Connor, 2013).

The SSI is an analytical tool that allows researchers to examine the user in new ways. It allows researchers to measure an individual subjects' performance within the system with a high degree of precision. The SSI can be used to develop better prediction algorithms or even produce systems with varying thresholds to allow for better interactions with consistently poor performing users. O'Connor's work shows that "there are adjustments to be made to obtain stable matching scores from individuals, which should improve the performance of biometric systems" (2013, p. 59).

2.6 The Human-Biometric Sensor Interaction Model

The human-biometric sensor interaction (HBSI) model "to demonstrate how metrics from biometrics (sample quality and system performance), ergonomics (physical and cognitive), and usability (efficiency, effectiveness, and satisfaction) overlap and can be used to evaluate overall functionality and performance of a biometric system" (Kukula et al., 2010, p. 1). There are several strengths associated with the HBSI model. The HBSI model allows for researchers and test administrators understand what errors are occurring, what is causing these errors to occur, and what areas to improve within the system so these errors do not occur.

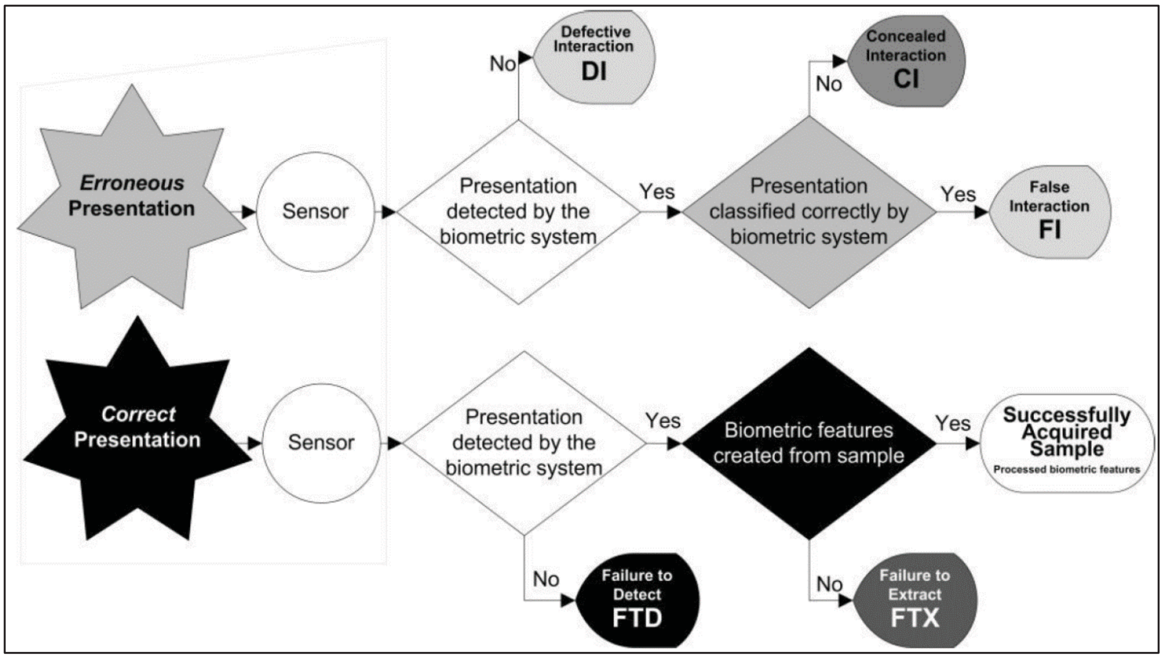

Figure 2.5 The HBSI Model (Kukula et al., 2010, p. 3)

Shown in Figure 2.5, the HBSI model begins with either a correct or erroneous presentation made by the user. This presentation is captured by the sensor. If the system does not detect the biometric features, either a failure to detect (FTD) or defective interaction (DI) occur for correct or erroneous presentation respectively. In the case of a correct presentation, if the presentation was detected but the features could not be extracted, a failure to extract error (FTX) occurs. In the case of an erroneous presentation, if that erroneous presentation is correctly classified as erroneous, the false interaction (FI) occurs. A concealed interaction (CI) is an erroneous presentation that is not correctly classified as such. A successfully acquired sample, also called successfully processed sample (SPS), occurs when the biometric features are created from a correct presentation. In the case of CI and SPS, these sample are stored in either the matching or enrollment subprocess of the general biometric model. The exact definitions for each error can be found below:

Erroneous Presentation: Any presentation, whether made with malicious intent or not, that was not performed to the specifications of the particular biometric sensor collecting the sample.

Defective Interaction (DI): "…occurs when a bad presentation is made to the biometric sensor and is not detected by the system" (Kukula et al., 2010, p. 2).

Concealed Interaction (CI): "…occurs when an erroneous presentation is made to the sensor that is detected by the biometric system, but is not handled or classified correctly as an 'error' by the biometric system" (Kukula et al., 2010, p. 2).

False Interaction (FI): "…occurs when a user presents their biometric features to the biometric system, which are detected by the system and is correctly classified by the system as erroneous due to a fault or errors that originated from an incorrect action, behavior, or movement executed by the user" (Kukula et al., 2010, p. 3)

Correct Presentation: Any presentation that was performed within the specifications of the particular biometric sensor collecting the sample.

Failure to Detect (FTD): "…the proportion of presentations to the sensor that are observed by test personnel but are not detected by the biometric sensor" (Kukula et al., 2010, p. 4). There are two types of FTD: system and external factor.

Failure to Extract (FTX): "…the proportion of samples that are unable to process or extract biometric features" (Kukula et al., 2010, p. 4).

Successfully Acquired Sample/Successfully Processed Sample (SPS): "…occurs if a correct presentation is detected by the system and if biometric features are able to be created from the sample. SPS result from presentations where biometric features are able to be processed from the captured sample, which are then passed to the biometric matching systems" (Kukula et al., 2010, p. 4).

2.7 Time

The notion of time as a construct is of critical importance within the biometrics community. The current model of time in the biometrics field is not consistently applied, as there are limited definitions that can be used. Researchers speak of very specific intervals of data collection that may be confusing and creates obscurity between studies, making them hard to compare. Time "is basically a human construct to fit the needs of humans as we grow and evolve, it stands to reason that we can and should rethink and try to adapt our ideas and use of time into something that will be more useful" (Weil, 2013). Namely, a new construct should be developed to fit the needs of the field. There are, however, established models and methodologies that start as a framework to begin creating a more robust definition of time.

2.7.1 Ambiguity in Biometrics Literature

The following statements are from past research in regards to time, length, or duration of a particular piece of research. While not intentionally malicious or deceitful, these examples show how confusing the reporting protocol for time can be.

"One set, in particular, the US-VISIT Point of Entry dataset (POE) contains all fingerprints collected by US-VISIT between January and June 2004" (Hicklin et al., 2005, p. 9).

"All of the iris images used in this study were acquired with the same LG 2200 iris imaging camera, located in the same studio throughout the four years of image acquisition" (Baker et al., 2006, p. 3).

"The database comprises 264,645 iris images of 676 unique subjects captured over 27 sessions" (Arora et al., 2012, p. 349).

"The final dataset was collected in four acquisition sessions, which spanned a total of 12 weeks" (Connaughton et al., 2012, p. 921).

2.7.2 Biometric Transaction Times

While the literature covering the topic of "time" in general is quite robust, the literature covering the topic of "time" in biometrics is oddly sparse in some areas yet incredibly detailed in others. Shown in Figure 2.6, operational times (Elliott, Kukula, & Lazarick, 2009) are specific lengths of time to perform different subcomponents initiated by either the subject or system and how these subcomponents contribute to the total transaction time. Time, in this function, is very short and is focused on increasing throughput by examining and enhancing particular aspects of the total transaction time. Once the user ends the transaction with the device, further recording of time in not performed. Operational time is an example of an implementation of measuring time.

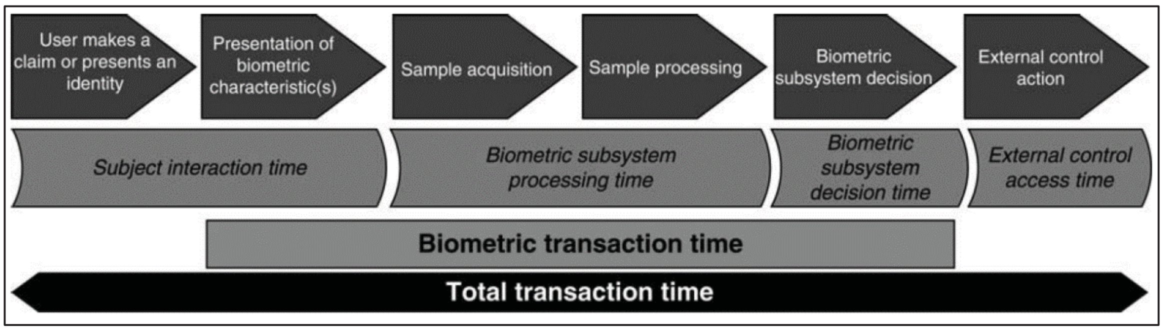

Figure 2.6 Operational Times

The following are definitions of the subcomponents of operational times (Figure 2.6):

Total Transaction Time: The "…sum of all the subcomponent periods of time associated with the biometric application system" (Elliott, Kukula, & Lazarick, 2009, p. 1023).

Overt Biometric Transaction Time: "This begins with the biometric sample presentation and ends with the biometric decision. Therefore, this includes the presentation of the biometric trait portion of the subject interaction time, biometric subsystem processing time, which includes sample acquisition and sample processing time, and the biometric decision time" (Elliott, Kukula, & Lazarick, 2009, p. 1023).

Subject Interaction Time: "…commences when a claim of identity is made (or presented)… The time ends when the individual has presented his/her biometric characteristic(s) and the sensor begins to acquire the sample" (Elliott, Kukula, & Lazarick, 2009 p. 1023).

Biometric Subsystem Processing/Transaction Time: "…the time taken for the system to acquire the biometric sample, to evaluate the quality of the sample, and if the quality is satisfied, to process that sample for comparison. For the samples of bad quality, the biometric system requests the subject to submit the biometric trait. The biometric subsystem processing time ends when either a comparison score or a request for re-submission is generated" (Elliott, Kukula, & Lazarick, 2009, p. 1023).

Biometric Decision Time: "…the time required by the biometric subsystem to generate an accept or reject response based on the comparison score and the decision logic" (Elliott, Kukula, & Lazarick, 2009, p. 1023).

External Operation Time: "…the time required to complete the application transaction" (Elliott, Kukula, & Lazarick, 2009, p. 1024).

2.7.3 The Relationship between Presentations, Attempts, and Transactions

ISO/IEC JTC 1 SC 37 defines the relationship that exists between presentations, attempts, and transactions (2006, p. 38). Presentations are synonymous with placements depending on the system. One or more presentations may be required to constitute an attempt. A failed attempt occurs after N presentations have taken place. One or several attempts may be necessary to produce a transaction. A failure to enroll or failure to match occurs after N attempts and constitutes a failed transaction. Sub-transactions are used to evaluate and study scenario evaluation more so than technology. Subject interaction with a device will comprise of several transactions.

2.7.4 ISO/IEC Terms

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) have created and adopted several terms and processes that are easily adaptable to the biometrics field. ISO 8601 was created in 1988 to resolve several issues and misconceptions in regards to dates and time. First, the designated method of pinpointing a specific time is designated as [hh]:[mm]:[ss] where [hh] pinpoints the hour of the moment in time (0-24), [mm] pinpoints the minute of the moment in time (0-60), and [ss] pinpoints the second of the moment in time. The second may go to as many decimal places as required to achieve required specificity. Additionally, time zone designators are also added to the end of the string such as Zulu time, which is a standardized time zone in which many communities such as the United States military, electrotechnical fields, and international broadcasts operate so individuals around the world can maintain the same clock.

For reporting the duration of an event, a longhand notation has been created. For example, P4Y2M1W4DT2H14M43S is the duration of an event that lasts four years, two months, one week, four days, two hours, fourteen minutes, and forty-three seconds. These are denoted by the designators in Table 2.B.

Table 2.B *Duration Annotation Notation*

Designator	Definition
P	The duration designator placed at the start of the duration period
Y	The year designator
M	The month designator
W	The week designator
D	The day designator
T	The time designator that precedes the time components of the representation
H	The hour designator
M	The minute designator
S	The second designator

These methodologies can then be merged to report precisely when an even begins the exact duration of that event. 2015-03-24T18:18:30.000Z/P4Y2M1W4DT2H14M43S is an example of this time interval reporting. In this case, the start of the point of interest began on 24 March 2015 at 18 minutes, 27 seconds, and 30 seconds Zulu time and lasted for four years, two months, one week, four days, two hours, fourteen minutes, and forty-three seconds. There is now a very accurate and precise point in time this example began and lasted for a very specific precise duration.

IEC 60050-113 (2011) has several very detailed definitions in regards to time that apply to biometrics research well:

Time (113-01-03): “One-dimensional subspace of space-time, which is locally orthogonal to space.”

Process (113-01-06): “Sequence in time of interrelated events.”

Time Axis (113-01-07): “Mathematical representation of the succession in time of instantaneous events along a unique axis.

Instant (113-01-08): “Point on the time axis.”

Time Interval (113-01-10): “Part of the time axis limited by two instants.”

Time Scale (113-01-11): “System of ordered marks which can be attributed to instants of the time axis, one instant being chosen as the origin.”

Date (113-01-12): “Mark attributed to an instant by means of a specified time scale.”

Duration (113-01-13): “Range of a time interval.”

Accumulated Duration (113-01-14): “Sum of durations characterized by given conditions over a given time interval.”

Calendar Date (113-01-16): “Date on a time scale consisting of a calendar and a succession of calendar days.”

Clock Time (113-01-18): “Quantitative expression marking an instant within a calendar day by the duration elapsed after midnight in the local standard time.”

2.7.5 Additional Definitions

There are several other definitions that must be stated to conclude the Literature Review. These definitions apply to the biometric duration model, which is explained in 3.2 and were developed for this research.

Visit: Collection of biometric data in one collection period, usually a subcomponent of a day, and includes all processes completed in that time frame (V#).

Group: The bundling of data collected during a visit into examined material for purposes of research (G#).

Day: A 24 hour period within a calendar day as governed by UTC, ISO, and IEC definitions. Days may be noted as calendar days (per ISO 60050-113-01-16) as long as the year, month, and week are also specified.

Week: A period of up to seven days within a calendar week as governed by UTC, ISO, and IEC definitions. Weeks may be noted as calendar weeks (per ISO 60050-113-01-16) as long as the year and month are also specified.

Month: A period of 28, 29, 30, or 31 days, depending on the month in question and the event of a leap year, within a calendar month as governed by UTC, ISO, and IEC definitions. Months may be noted as calendar months (per ISO 60050-113-01-16) as long as the year is also specified.

Year: A period of 365 or 366 days, depending on the event of a leap year, within a calendar year as governed by UTC, ISO, and IEC definitions. Years may be noted as a calendar year (per ISO 60050-113-01-16).

2.8 Chapter Summary

The function of any biometric system, whether it be physiological or behavioral, is to identify or verify a user by comparing information at the point of interaction with a previously enrolled template of distinct, identifiable characteristics. Literature has stated that the iris is stable over time as a biometric modality (Daugman, 2004) but has not to date proven how stable the iris is. Current literature is also ambiguous in the reporting and classifying of time related events. ISO and IEC have provided adequate definintions and terminology that may be applied to the biometrics community.

CHAPTER 3. METHODOLOGY

The purpose of this study was to determine the stability of users over time. The first step was to process the images from a data collection which was collected during a 2013 Purdue University research project. The next step was to process the dataset using a matching algorithm. Next, scores that the matching algorithm produced were used to create a zoo plot for each subject. After the creation of the zoo plots, a Stability Score Index (SSI) was computed across all of the users' visits. SSI were then used to determine the statistical significance of the findings. However, before data processing could begin, a better definition of time in biometrics had to be established.

3.1 Time Issues

Time within the field of biometrics has been an ambiguous entity at best and an ignored factor at worst. With consistent reporting issues and poor definition of study duration in past work, this research will construct the biometric time model to define these parameters more accurately. "All of the iris images used in this study were acquired with the same LG 2200 iris imaging camera, located in the same studio throughout the four years of image acquisition" (Baker et al., 2006, p. 3) is just one of many examples where reporting of time and the overall concept of time is not fully developed. To solve this information gap, the biometric time model was created.

3.2 Biometric Time Model

The biometric time model was created Petry, Elliott, Guest, Sutton, and O'Connor 2015 to model the relationship between the general biometric model and human-biometric sensor interaction (HBSI) model. Additionally, the model expands beyond the general biometric model and HBSI model to encapsulate the summaries of variables of interest collected during user interactions. Figure 3.1 shows the model. This model is useful for understanding how different time durations relate to each other. Before the development of this model, these relationships could not be fully understood or expressed.

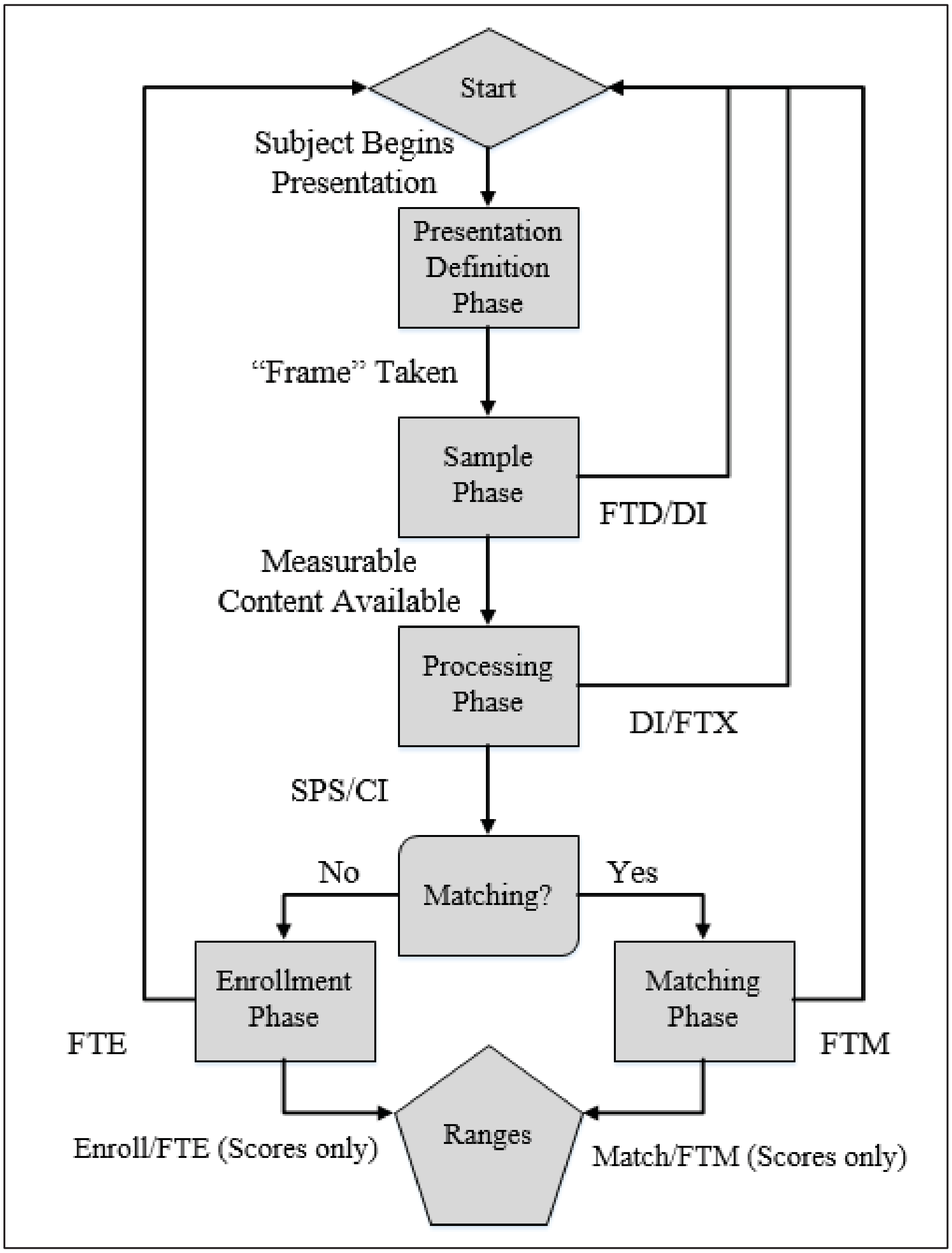

Figure 3.1 Biometric Time Scale Model

3.2.1 Phases

Phases occur as part of the general biometric model and HBSI model. The three models (general biometric, HBSI, and biometric time scale) are all mapped together and are represented by phases. The phases ultimately result in the enroll/match phase that is the summary of all scores, metrics, and other items measured.

3.2.1.1 Presentation Definition Phase

The presentation definition phase begins outside of the general biometric model. These are the interactions and processes that the user undergoes before and during data capture. It is these interactions that are determined to be "erroneous" or "correct" presentations in the HBSI model. Categorizing user interactions can perform in two ways: manually and automatically. Manual categorization can be achieved by examining video evidence that is separate from the biometric capture system and having a test administrator later categorize the user interactions. In automatic categorization, an advanced human motion capture device is used to classify predetermined interactions performed by the user. Classification can be carried out in real time to provide feedback to the subject or at a later date. The actions that are categorized from this section can yield more information on how subject interactions can affect system performance.

3.2.1.2 Sample Phase

The sample phase consists of the smallest, most discrete unit of measurable content that is collected from a sensor. These units may be collected as individual figures in discrete capture systems or as frames in continuous capture systems. This phase occurs in the presentation sub-system of the general biometric model. HBSI errors include DI and FTD. If these errors occur, move back to start.

Figures are the smallest, most discrete unit of measurable content collected in the data capture sub-system of a discrete capture system. One or many figures are collected in order to obtain a sample. Frames are the smallest, most discrete unit of measurable content collected in the data capture sub-system of a continuous capture system. One or many frames are collected in order to obtain a sample.

3.2.1.3 Processing Phase

One or more samples are collected until a sample that contains measurable properties of the particular modality are obtained. These properties are subjected to the three initial processes of the signal processing sub-section (segmentation, feature extraction, and quality control) of the general biometric model. HBSI errors include FI and FTP. If these errors occur, move back to the start.

3.2.1.4 Enrollment Phase

In the case of system enrollment, the template created after the signal processing subsystem is stored in the data storage subsystem. This template and associated metrics are stored in enroll phase of the biometric time model regardless if a result of enrollment or failure to enroll (FTE) occurs. If an FTE occurs, move back to start. If a CI from the HBSI model occurs, look back presentation definition phase and determine the error made by subject. If an SPS from the HBSI model occurs, end the phase portion of the model and submit metrics to immediate range summary.

3.2.1.5 Matching Phase

In the case of system matching, either verification or identification, the metrics created from the sample after the signal processing subsystem are sent to the matching sub-system of the general biometric model. These metrics are compared to a stored user located in the data storage sub-section. If an FTM occurs, add metrics to the immediate range statistical summary and move back to start. If a CI from the HBSI model occurs, look back presentation definition phase and determine the error made by subject. If an SPS from the HBSI model occurs, end the phase portion of the model and submit metrics to immediate range summary.

3.2.2 Ranges

All ranges occur on a traditional Gregorian time frame and UTC. These ranges occur in the traditional terms "days", "weeks", "months", and "years". Ranges are summaries of the previous range or, in the case of immediate range, enroll and matching phases.

3.2.2.1 Day Range

A summary of all metrics from enrollment, FTE, match, FTM, and any another other metrics of interest collected from 0:00.00 UTC to 23:59.99 UTC for a user, system, or both. After such time, a new immediate range begins. The day range maps directly to the calendar day.

3.2.2.2 Week Range

A summary of all metrics from enrollment, FTE, match, FTM, and any other metrics of interest collected from one to seven immediate ranges for a user, system, or both. When an eighth day range occurs or a new Gregorian calendar week begins (starts on Sunday), a new week range begins. The week range maps directly to the calendar week.

3.2.2.3 Month Range

A summary of all metrics from enrollment, FTE, match, FTM, and any other metric of interest collected from up to four week ranges points for a user, system, or both. When a fifth week range occurs or a new Gregorian calendar month begins, a new medium range begins. The month range maps directly to the calendar month.

3.2.2.4 Year Range

A summary of all metrics from enrollment, FTE, match, FTM, and any metric of interest collected from up to twelve month range points from a user, system, or both. When a thirteenth medium range occurs or a Gregorian calendar year begins, a new long range begins. The year range maps directly to the calendar year.

3.2.2.5 Life Range

A summary of all metrics from enrollment, FTE, match, FTM, and any other metric of interest collected over the life span of the user, system, or both.

3.2.2.6 Intermediate Ranges

Intermediate ranges exist as components or combinations of the other ranges and may be added and removed to explain data in the most accurate manner. For example, an intermediate range of a day would be the hour range. 24-hour ranges would constitute a day range.

Table 3.A *Biometric Time Model Standard Nomenclature, Metrics, and Duration*

Standard Nomenclature	Biometric Time Model Term	Metric	Duration
-	Presentation Definition Phase	ms	Start - Sample Phase
-	Sample Phase	ms, FTD/DI Rate	Presentation Definition Phase - Processing Phase
-	Processing Phase	ms, FTX/FI Rate	Sample Phase - Enrollment/Matching Phase
-	Enrollment Phase	ms, FTE/Enroll Metrics	Processing Phase - Day Range
-	Matching Phase	ms, FTM/Match Metrics	Processing Phase - Day Range
Day	Day Range	Metrics from one calendar day	24 hours, 1440 minutes, 86400 seconds, etc
Week	Week Range	Metrics from one calendar week	Seven days
Month	Month Range	Metrics from one calendar month	28, 29, 30, or 31 days depending on the month a occurance of a leap year
Year	Year Range	Metrics from one calendar year	12 months
Life Cycle	Life	Metrics from life of user or system	Frist Presentation Definition Phase - Last Presentation Definition Phase

3.3 Data Collection

The data analyzed in this research were collected from the summer of 2012 to the summer of 2013 for a Department of Homeland Security study (Elliott, 2014). Data were collected at Purdue University on the West Lafayette, Indiana campus. Data collection was conducted under general office conditions, and the testing equipment was used under the manufacturer's general guidance procedures. Both right and left iris images were obtained for the original study. An in-depth report on the data collection methodology can be found in Elliott (2014).

3.4 Data Analysis

Data analysis consisted of seven distinct phases: data processing, matching of subjects, file conversion, zoo matrix and zoo analysis creation, stability score calculations, and final analysis. The following sections will go over these phases in detail.

3.4.1 Data Processing

The first step of data analysis was to process the existing data collected from the Purdue University ICBR database. This dataset consists of images acquired from 262 subjects over eight visits. Data collection began on 11 June 2012 and lasted for 1 year and 8 days (2012-06-11/P1Y0M0W8D). The time scope of interest for this report was in the month range. The collection period of interest for this report began on 11 June 2012 and lasted for 1 year and 8 days (2012-06-11/P1Y0M0W8D). Brockly (2013) found that the collection protocol and test administrator errors from visit one were different enough from the other visits to remove visit one from this research. Visits were inspected to determine the number of subjects that attend all of the remaining visits. The total number of subjects at all visits came to 31. The number of images per subject, however, varied considerably from 0-72. The original test protocol called for each subject submitting 20 samples of each iris collected together. If the attempt did not yield both irises, the subject tried again. This process was repeated until 25 attempts were completed after which point the subject did not submit any more attempts. Therefore, each subject having 40-50 images (two per eye per capture) was expected. The results of this count are shown in Table A1.

At this time, the number of images per individual iris were examined. According to Paone and Flynn:

> The results of an all-pairs matching comparison for each of the three algorithms support that the menagerie classifications are algorithm dependent, specifically Doddington's weak users and Yager and Dunstone's classifications. When breaking the overall dataset into subsets based on the left and right iris, the biometric menagerie classifications do not agree when comparing irises of the same subject. Doddington's weak users and all of Yager and Dunstone's classifications are sensitive to which iris is chosen when matching a user (2011, p. 6).

Paone and Flynn determined that irises are independent of each other as far as zoo classifications are concerned. Independence allows each iris from each subject to be used independent from one another, effectively doubling the sample pool from 31 original subjects to 62 potential irises. Each subject iris should have between 20 and 25 images. Shown in Table A2, visit two was missing several images for multiple subject irises after data cleaning. Each subject iris that did not meet the image count requirements must be removed because each iris cannot be examined across visits if a particular visit had a small number of images. In order create the largest subject iris pool as well as the highest count requirement, visit two was removed from this research.

To establish a final dataset pool, each subject iris must have met an image count requirement across all visits. The final image count requirement was determined to be 12 images per subject iris. This count was established based of the data. It allowed for the most subject irises to be selected while still maintaining a large enough image candidate pool for randomization. If a particular subject iris did not meet that requirement that subject iris was removed from the pool. However, since the other iris is different, it was maintained in the pool as long as it meets the image count requirement. Table A3 shows the final pool of subject irises for this research. Each subject iris had between 12 and 25 images according to collection protocol. However, some visits have more than 25 images (36-L visit eight, for example). These images were manually ground-truthed, and in all cases, there were no discrepancies or merged subjects. These subjects may have accidentally been told to submit for extra sample collection. Since they were, in fact, the correct subject iris, they were kept in the final pool. The final pool of subject irises consisted of 60 unique irises.

In order to simplify reporting and avoid confusion, the visits were renumbered. Visit three was renumbered as visit one since it is the first visit this research examined. Visit four was be renumbered as Visit two since it is the second visit this research examined. The same logic follows for the remainder of the visits. Each subject iris image count was truncated to 12 images per visit. These images were the first 12 images collected by the sensor for each iris. Dates of visits are located in Table 3.B. Now that each subject iris had the same number of images with the images occurring sequentially from the first captured, the next subprocess of data processing occurred: randomization.

Table 3.B *Dates of Visits*

Visit	Start Date	End Date	Days
1	4/11/2013	5/9/2013	48
2	4/22/2013	5/29/2013	37
3	4/26/2013	6/5/2013	40
4	5/6/2013	6/12/2013	37
5	5/14/2013	6/18/2013	35
6	5/28/2013	6/18/2013	21

3.4.2 Randomization

Randomization was critical in this research for several reasons. First was to eliminate effects such as habituation of the user over time. Namely, the user may get better at interaction with the capture device within the visit. So by randomly selecting images, they each had as much likelihood of being selected and examined which mitigates habituation. Randomization was also performed to eliminate any consequences from order of effects issues. There potentially could be some element of unknown correlation between images that were collected sequentially. Finally, randomization gives each of the 12 images per subject iris the equal likelihood of being one of the three ultimently selected and examined.

3.4.2.1 Proceeding Intra-Visit Stability Research

When examining the stability of the iris within a visit as a precursor to this research, stability was found. Each visit was researched independently with the same subject iris set for each visit. The biggest differences in the methodologies of these two works of research were the duration scale of interest (intra-visit and monthly) and randomization. The work that looked at intra-visit did not use randomization. The first three sequential subject iris images were clustered together. These clusterings were then added to grouping one, the next three as grouping two, the third three as grouping three, and the final three as grouping four. Each grouping consisted of the match scores of one subject iris, which required three images to produce. The stability score index (SSI) of each iris grouping was then calculated. A Kruskal-Wallis non-parametric test was run on the non-normal data and yielded statistical stability both forwards and backward. This meaning that the match scores were statistically stable both forwards (Grouping 1 – Grouping 2 for example), backwards (Grouping 4 – Grouping 3 for example), and jumping groups (Grouping 1 – Grouping 4 for example). These findings show that a cluster of three images, no matter when in succession these images were taken will yield stability within the visit.

3.4.2.2 Across Visits Randomization Plan

Based off of the findings from the intra-visit research, three images per subject iris per visit were selected at random. Randomization was used to mitigate the potential for effects such as habituation by the subject. Table A4 details which images were selected for each subject iris per visit. These images were selected by a random number generator in Microsoft Excel. Each subject iris was examined individually and did not take into account other images chosen from the other subject irises. Each image for the subject iris within each visit was given a random value from the random number generator function. The three images that had the highest randomly assigned number were selected. The selection process described was then repeated for each visit for that subject iris and then for all visits for all subject irises.

3.4.3 Matching of Subjects

All collected images were processed using Megamatcher 4.0, a commercially available software developed by Neurotechnology, a company that produces biometric algorithms. Megamatcher is a tool that can be used for fingerprint, face, voice, iris, and palm recognition, segmentation, and identification. The quality threshold for this data collection was set at zero. All images were matched to all other images in the data set, including the original image. The software used an image to create an output providing two numbers: a genuine score and an impostor score. A genuine score is the result of a ground-truth, verified self-match to an existing template. An interaction will be defined as any time the subject attempts to interact with the information collection system. Once all images were matched, the user impostor and genuine scores were produced in a Microsoft Excel spreadsheet.

3.4.4 File Conversion

The Excel files that were created in the previous stage (3.4.3) were converted into Oxford Wave Readable (OWR) files. This conversion is necessary for the zoo plot software, Oxford Wave, which was used in the next stage.

3.4.5 Zoo Matrix and Zoo Analysis Creation

With all of the necessary data collected, a zoo plot was created for each visit. The zoo matrix outputs a zoo plot and a zoo analysis. These scores are plotted on an X-Y scatter plot with genuine scores in the X direction and the impostor scores in the Y direction. All user genuine-impostor data points are plotted together for a given dataset to identify how these user scores relate to each other. The zoo plots maximum and minimum bounds were standardized across all datasets. The maximum and minimum genuine and impostor score of all datasets were used to define the outer bounds of all created zoo plots so all plots are scaled to the same size. Scaling allows for different zoo plots to be visually compared. A sample zoo plot is shown in Figure 3.2. Zoo plots segregate user scores into five classifications: Normal, Phantoms, Worms, Chameleons, and Doves. These are the Yager and Dunstone classification. A zoo plot was generated for each interaction period for a total of six zoo plots. The genuine and impostors are the numerical output of the zoo matrix and was used in the following stage, stability score index creation.

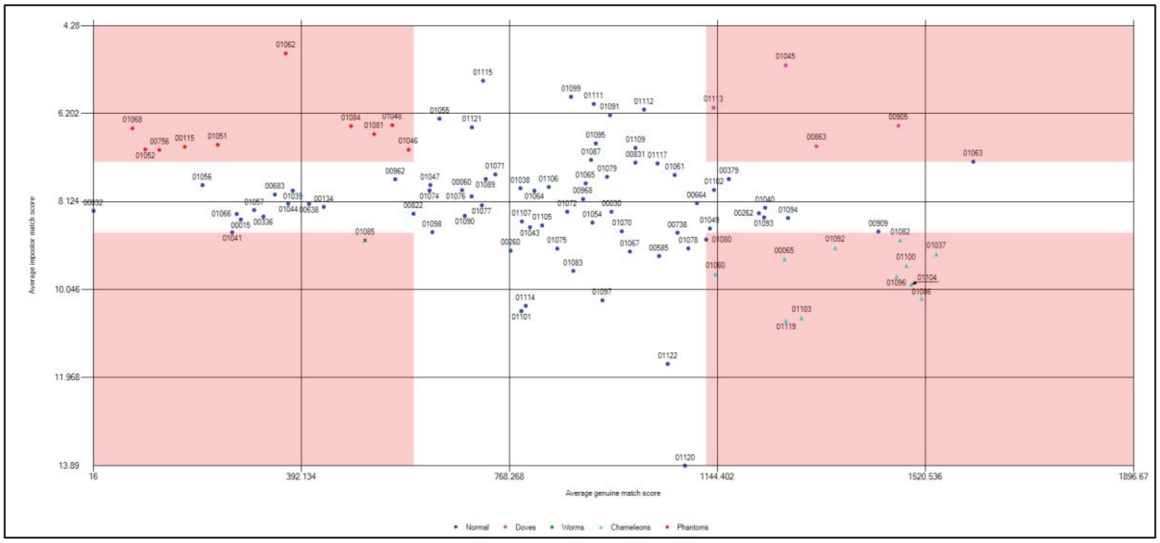

Figure 3.2 Zoo Menagerie Example 2

3.4.6 Stability Score Index Calculation

Next, the Stability Score Index (SSI) was calculated to further analyze the gathered data and calculate the stability of each subject iris. The genuine score of the initial position of the data point of interest and the genuine score of the subsequent data point of interest are designated as x_1 and x_2. The impostor score of the initial data point of interest and the impostor score of the subsequent data point of interest are designated as y_1 and y_2. x_{max} and x_{min} represent the maximum and minimum genuine scores obtained across all time intervals. Similarly, y_{max} and y_{min} represent the maximum and minimum impostor scores obtained across all time intervals. The variables were arranged and computed to give the SSI, shown below in Equation 2.6 (O'Connor, 2013, p. 52). The resulting SSI had a range of 0 to 1 with zero representing a perfectly stable score across two interaction periods, visits in this case, an SSI score of one represents the maximum possible movement across visits.

3.4.7 Final Analysis

Final analysis constitutes analyzing the data runs with the statistical software package, Minitab 17. Two primary applications were used within the software package, a graphical summary of the basic statistics and a Kruskal-Wallis test.

An analysis of the basic statistics outputs several pieces of information. This information includes a histogram, a boxplot, 95% confidence intervals for mean, median, and standard deviation, and quartiles. Information gathered from this summary was used to describe the data. Additionally, it was used to compare the different datasets to each other and to determine the subsequent tests.

The Kruskal-Wallis test was used to determine if the medians of two or more groups of data differ, assuming that the distributions of the data are similar. The Kruskal-Wallis reports a p-value, which is compared to a set alpha level of 0.05. These values were used to either fail to reject or reject the null hypothesis. If the p-value is less than the alpha level, the null hypothesis, H_0, is rejected. For this research, the hypothesis tests were as follows:

H_0: There is no statistically significant difference between the medians of the stability scores

H_α: There is a statistically significant difference between the medians of the stability scores

3.5 Threats to Validity

There are seven threats to consider when concerned about internal validity: history, maturation, testing, instrumentation, selection bias, statistical regression, and mortality effects (Sekaran, 2003). While each of these threats presents distinct dangers, instrumentation and statistical regression are the most relevant to this study. Instrumentation could play a role in inadequate performance analysis if the software utilized did not perform to specifications. Statistical regression as a threat is mitigated by using a relatively large sample size to lessen the effect of any one subjects' impact on the sample.

External validity is also a concern because the data utilized for this research encompass only the subject pool of the West Lafayette campus of Purdue University. The study can only be generalized to fit within the sample of that location. This information was collected and stored at an earlier time from this area and may not necessarily be generalized to other situations or current biometric acquisition technology.

3.6 Chapter Summary

Chapter Three established the methodology that was followed for this research. Match scores were used to create SSI which were analyzed with a Kruskal-Wallis non-parametric test to determine if the average mean SSI are statistically different from multiple visits spanning at least a month in between.

CHAPTER 4. RESULTS

In this chapter, the results of this research will be presented. Contents will include three major sections: demographics, stability of the iris within each visit, and stability across six visits. Output will be presented as statistical tests, detection error trade-off (DET) curves, zoo plots, and other graphical displays.

4.1 Demographics

Age, gender, and subject-declared ethnicity were collected for this study. Each subject attended all examined visits. Therefore, the demographics are reported for the entire research period. Due to Purdue University being predominantly made up of college-aged students, most subjects were in the younger age frame (Figure 4.1). There was a fairly good distribution of males and females for this research (Figure 4.2). Additionally, this dataset was prodominantly made up of Caucasians and may not be representative of a more global dataset (Figure 4.3).Remember, there were 32 total subjects for this research. However, only 60 of the possible 62 subject irises meet the image count requirement.

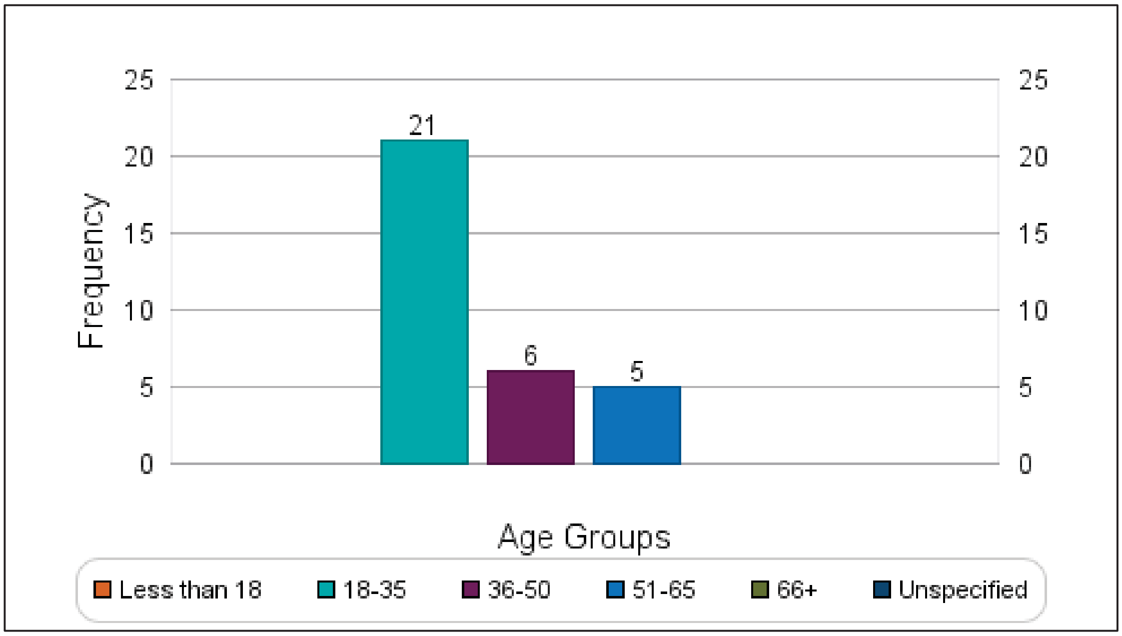

Figure 4.1 Age Groups of Subjects

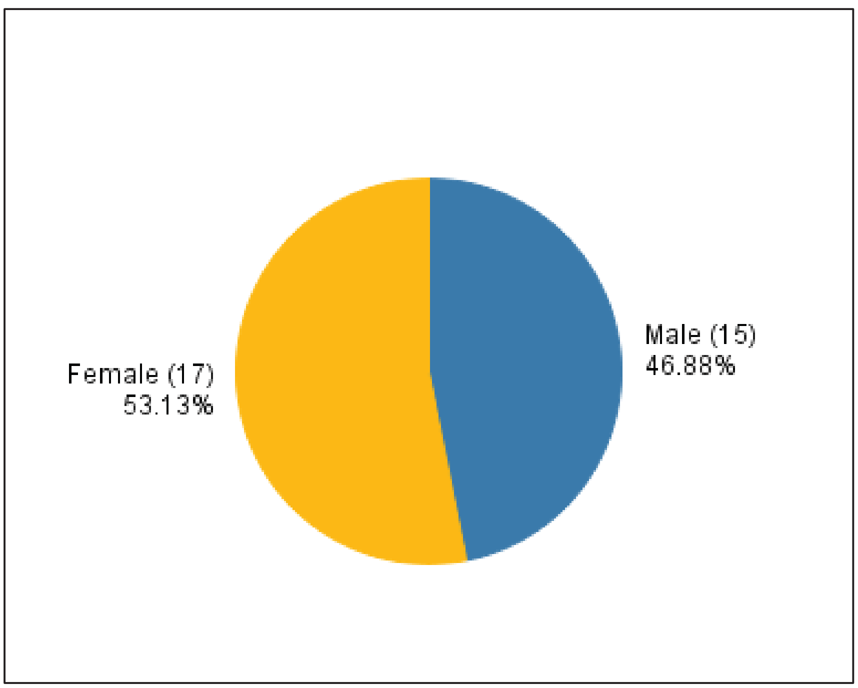

Figure 4.2 Gender of Subjects

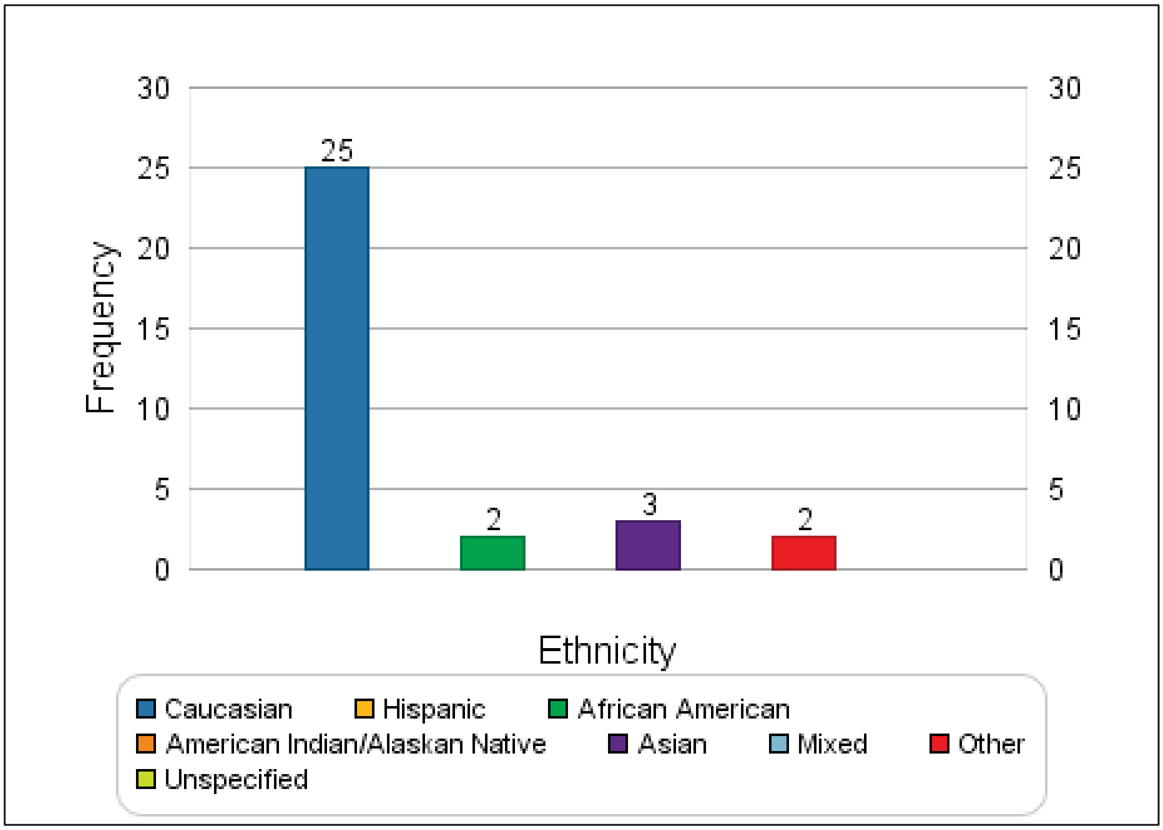

Figure 4.3 Self-Reported Ethnicity of Subjects

4.2 Iris Stability within a Visit

Before stability across several visits can be examined, intra-visit stability needed to be researched. Each of the six visits was reviewed for intra-visit stability before being considered for several visit stability. This was completed as part of an undergraduate class at Purdue University. Visit one was found to be stable across all subject irises (Brown et al., 2015), visit two was found to be stable (Anydiewu et al., 2015), visit three was found to be stable (Fevig et al., 2015), visit four was found to be stable (Boyle et al., 2015), and visit five was found to be stable (Bartley et al., 2015) throughout all groupings. Visit six (Hermann et al. 2015) was also found to be stable across three of the four groupings. The second grouping of the four was found statistically unstable (p value of 0.044). No reason for this instability could be found. Quality metrics were also examined specifically for visit six with no clear issues found. Additionally, aging was eliminated as a potential cause due to the short time frame of collection (one visit that lasted no more than ten minutes). Each of the six visits was found to be stable within the visit, so each visit was used for this research.

4.3 Stability across Visits

Once stability within a visit was been determined, stability across those visits could be ascertained. There were several test performed on the data including Anderson-Darling normality test, a statistical test based on the normality, detection error trade-off (DET) curve creation, zoo plots creation, and scatter plot creation. Plots and graphs were created first to help understand and visualize the data. The data was then checked for normality. Once the degree of normality was determined, the appropriate statistical test was performed.

4.3.1 Scatterplot and DET Plot Analysis

The following section details plots and graphs first created to start drawing conclusions from the data. Each visit includes a scatter plot of the genuine and impostor scores and DET curves. These figures give detailed information about performance within a single visit.

4.3.1.1 Scatterplots

Figure 4.4 – 4.9 show scatter plots of sample number versus score. H1, denoted by red circles, are impostor attempts while H0, denoted by the blue triangles, are genuine attempts. There are three distinctive sections of these graphs. The first is the very high genuine scores. The second is the clustering of genuine attempts that range from a score of approximenlty 1000 to just above the clustering of impostor attempts. The third range is genuine attempts with scores so low they are mixed with the impostor scores. These subject may cause serious issues with the results and may need to be treated as outliers. It should be noted that only visit one and visit two have genuine and impostor scores that are located in the same range.

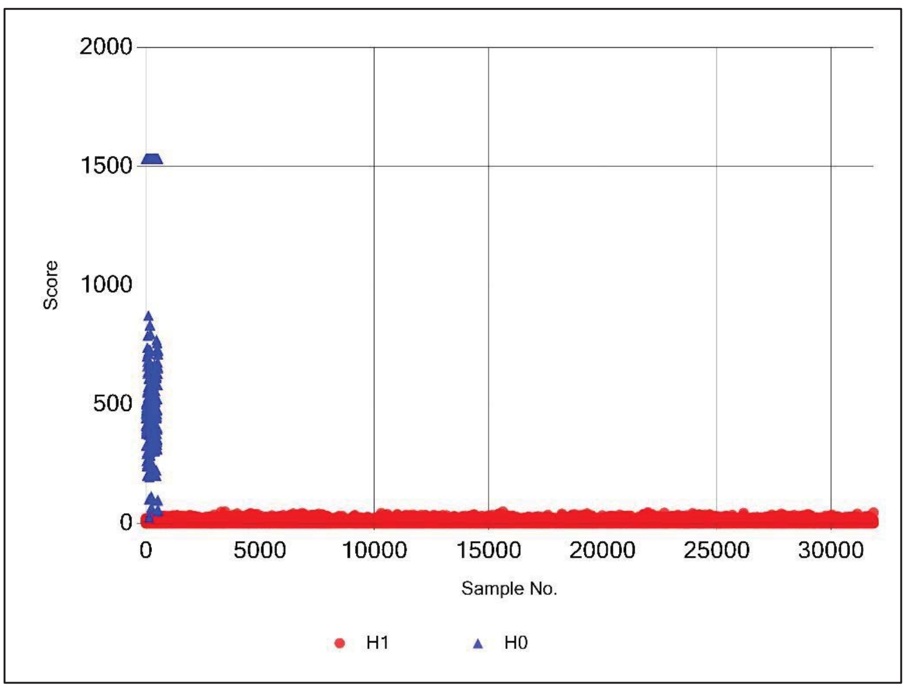

Figure 4.4 Visit One Scatter Plot of Sample Number vs. Score

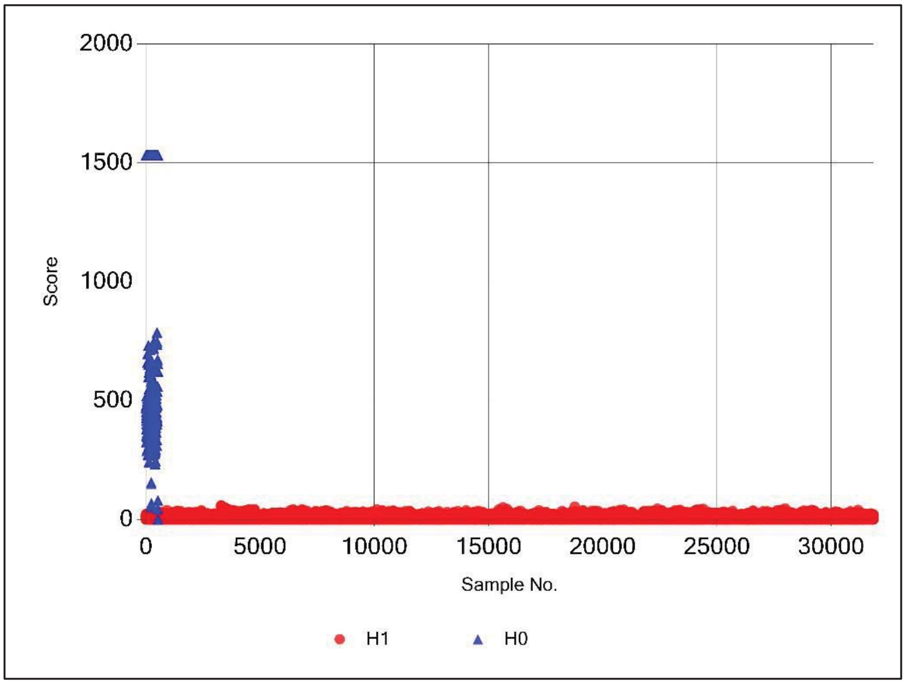

Figure 4.5 Visit Two Scatter Plot of Sample Number vs. Score

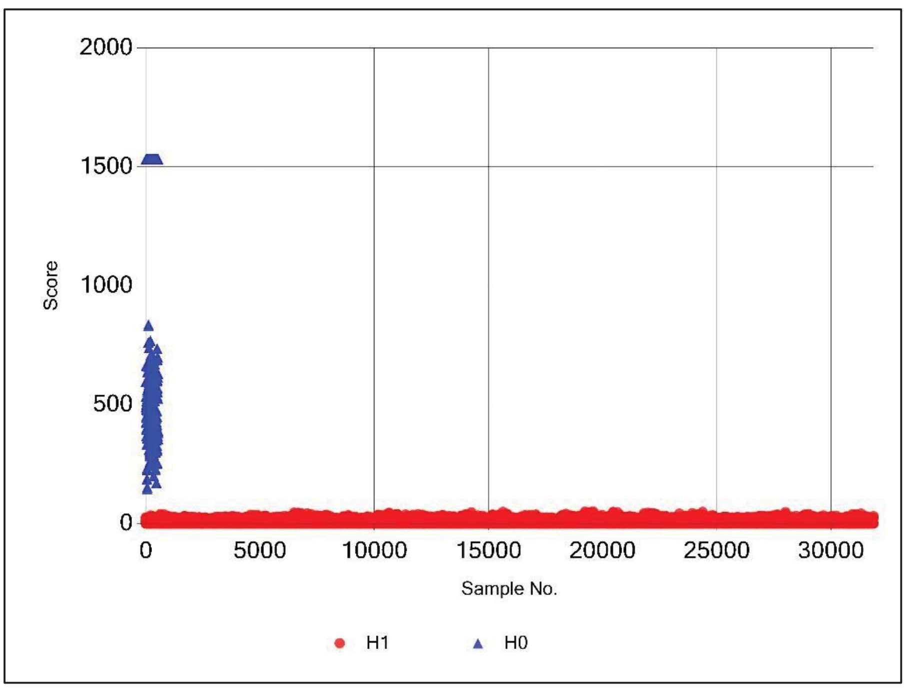

Figure 4.6 Visit Three Scatter Plot of Sample Number vs. Score

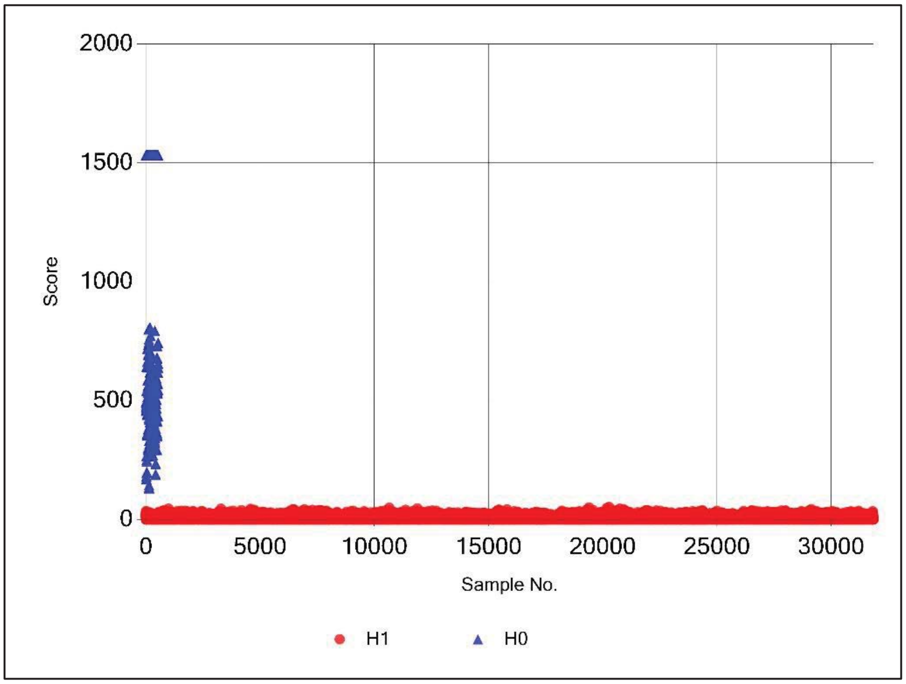

Figure 4.7 Visit Four Scatter Plot of Sample Number vs. Score

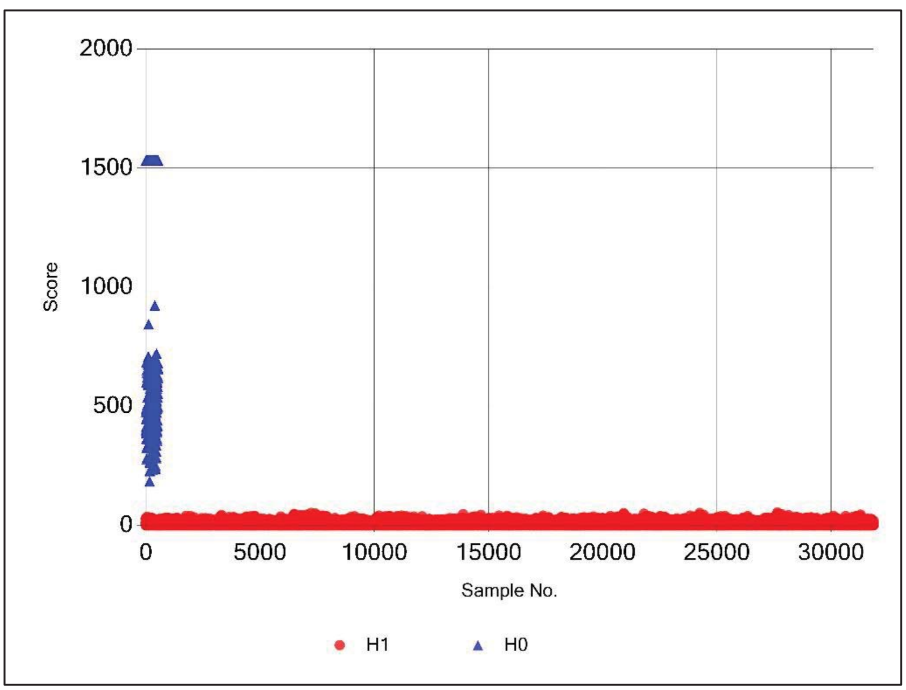

Figure 4.8 Visit Five Scatter Plot of Sample Number vs. Score

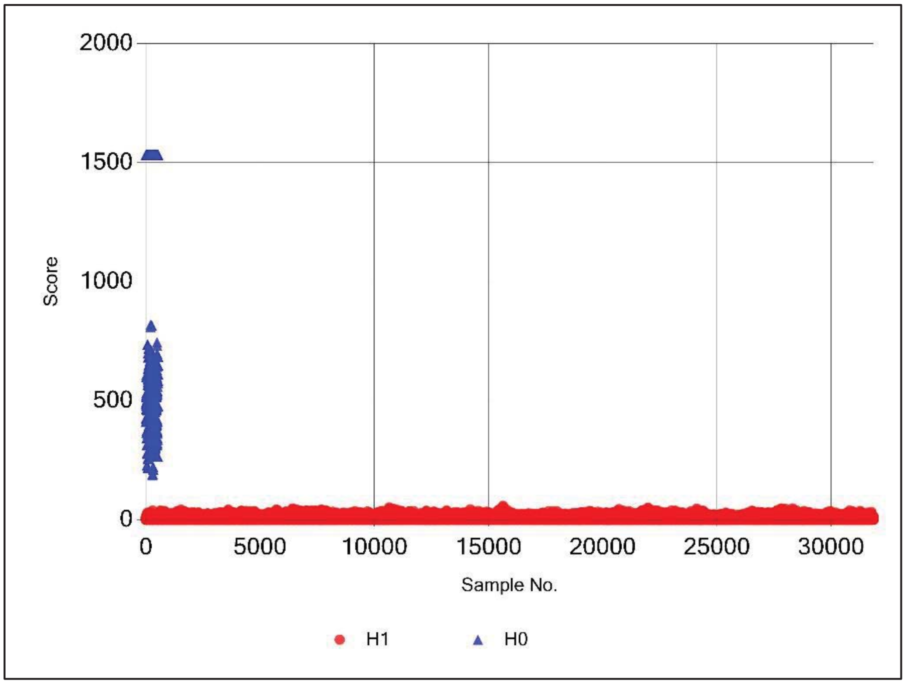

Figure 4.9 Visit Six Scatter Plot of Sample Number vs. Score

Iris score stability at this holistic view can be called into question. Because the scatterplots are not identical, they do not have the same scores. To determine the impact of this variation, further analysis was required.

4.3.1.2 DET Curves

Detection error trade-off (DET) curves are a “modified ROC curve that plots error rates on both axes (false positives on the x-axis and false negatives on the y-axis)” (ISO/IEC JTC 1 SC 37, 2005, p. 7). DET curves are used to measure overall system performance.

Table 4.A displays the DET curve summary of false reject rate (FRR) at different levels of false accept rates (FAR) for all six visits and includes the equal error rate (EER). Figure 4.10 – 4.12 show the DET curves for visit one, visit two, and visit three through six respectively. Visit three through six had the same DET curve. As noted in section 4.2.1.1, visit one and visit two displayed the most variation in FRRs at varying FARs as well as EERs. The other visits did not have any variation in FRRs or ERRs.

Table 4.A *FRR at Different Levels of FAR – DET Curve Summary V1-V6*

Visit Number	FAR			EER
	1	0.1	0.01	
V1	0.27	0.37	0.37	0.3547
V2	0.37	0.37	0.89	0.3798
V3	0.00	0.00	0.00	0.0000
V4	0.00	0.00	0.00	0.0000
V5	0.00	0.00	0.00	0.0000
V6	0.00	0.00	0.00	0.0000

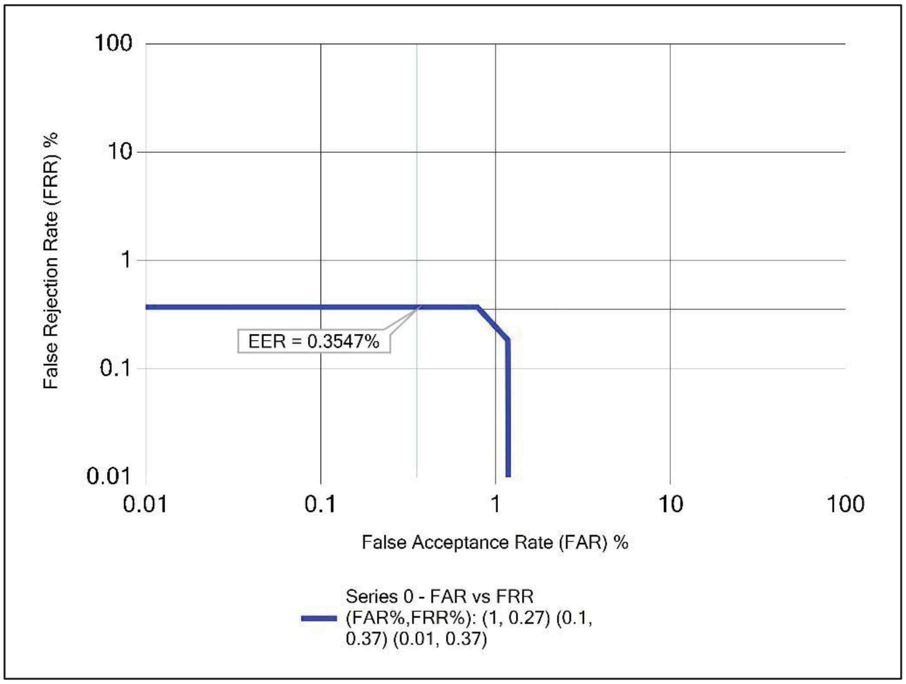

Figure 4.10 DET Curve Visit One

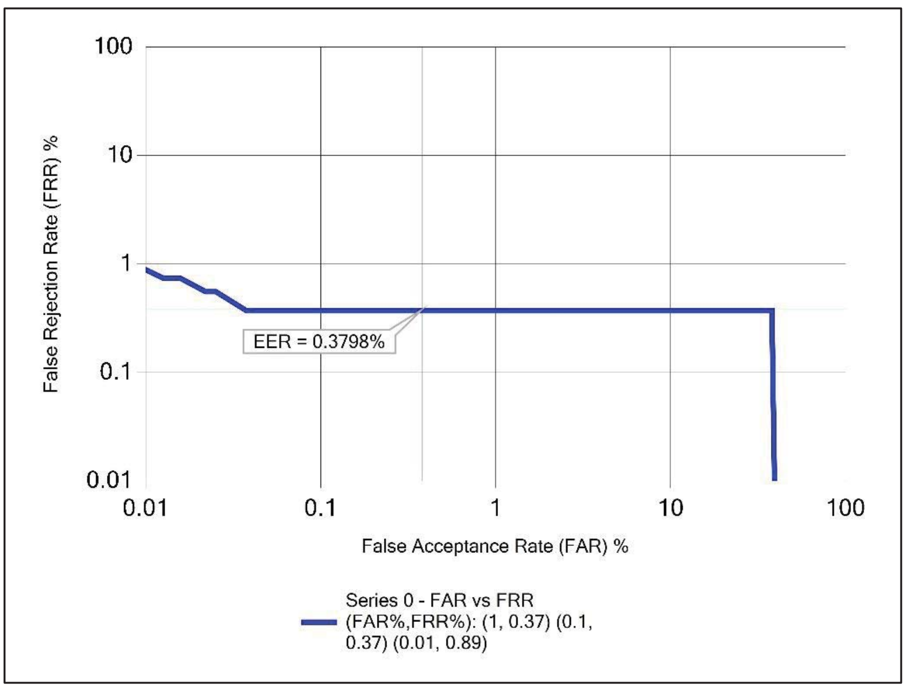

Figure 4.11 DET Curve Visit Two

As in 4.3.1.1, at this holistic view, iris performance stability is called into question. Grother et al. (2013) examined iris stability as well. These researchers concluded their study once an exhaustive analysis of DET curves was complete. However, DET curves do not tell the whole story. By ending analysis at this stage, vital individual subject iris information may be missed. Visit one and visit two show performance instability while visit three thought six do not. What could not be determined at this point, though, is individual subject iris match score stability. A zoo analysis was performed to identify the individual match scores of each subject iris.

4.3.2 Table of Zoo Animals

Table B1 displays the Yager and Dunstone classifications of each subject iris per visit with the associated genuine and impostor score. The maximum and minimum genuine and impostor scores for the entire dataset were calculated. The values are located in

Table 4.B. These values were used to set the bounds of the Yager and Dunstone classification zoo plots.

Table 4.B *Maximum and Minimum Genuine and Impostor Scores*

Genuine Minimum	Genuine Maximum	Impostor Minimum	Impostor Maximum
41.665	770.001	1.072	8.289

4.3.3 Zoo Plots

The zoo plots in Figure 4.12 – 4.18 show the spread of genuine and impostor scores per subject iris for each visit. Each plot was created with the same X and Y coordinate system so each plot could be compared both visually and mathematically to one another. Upon visual examination, these plots show that the majority of subjects are located in the normal classification with a fewer number in the other classifications. Additionally, the figures are all different from each other. The scores, therefore, are different from visit to visit.

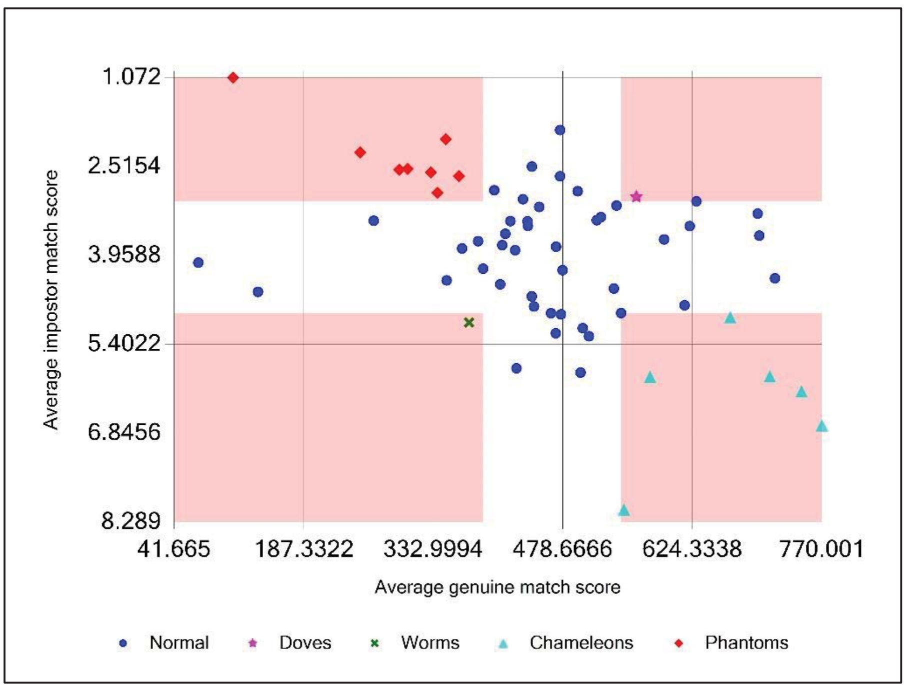

Figure 4.12 Zoo Plot Visit 1

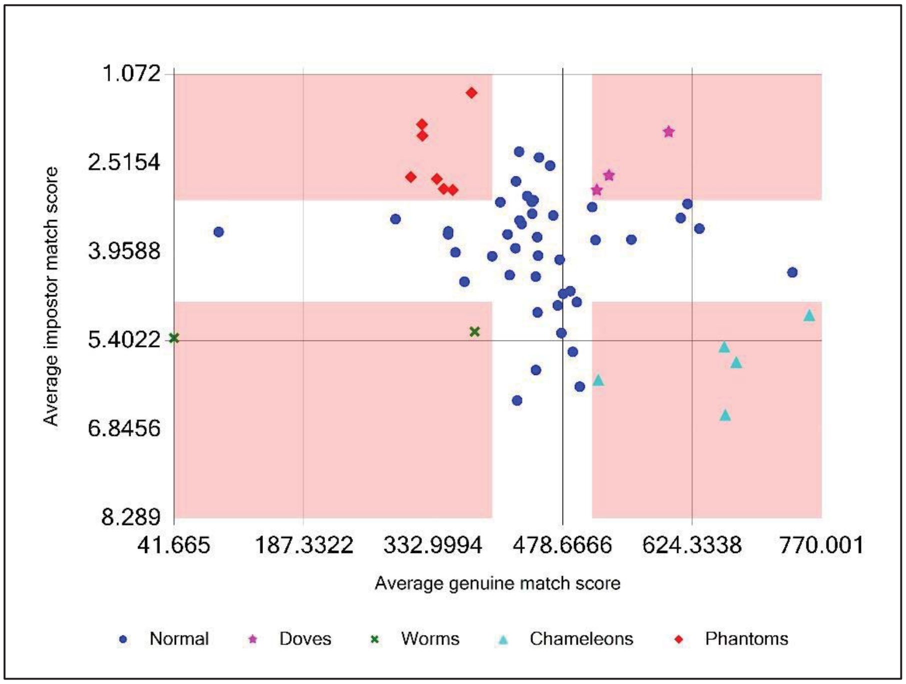

Figure 4.13 Zoo Plot Visit 2

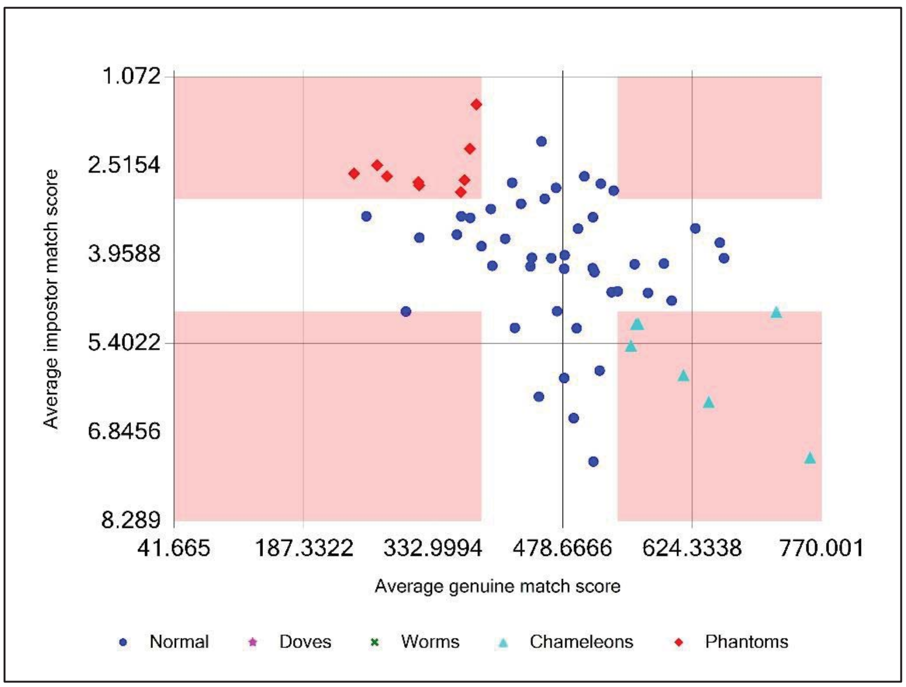

Figure 4.14 Zoo Plot Visit 3

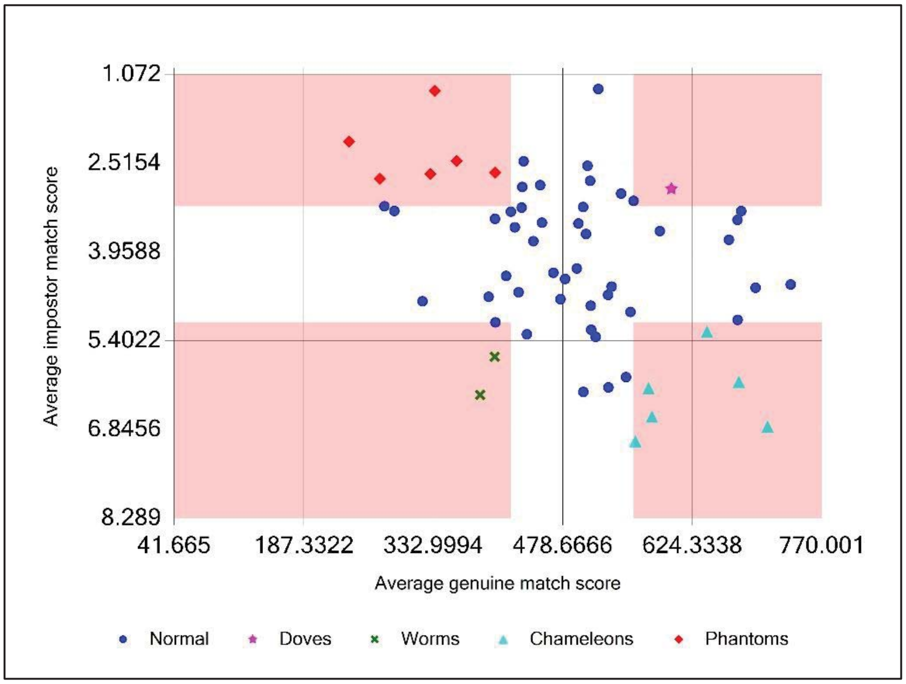

Figure 4.15 Zoo Plot Visit 4

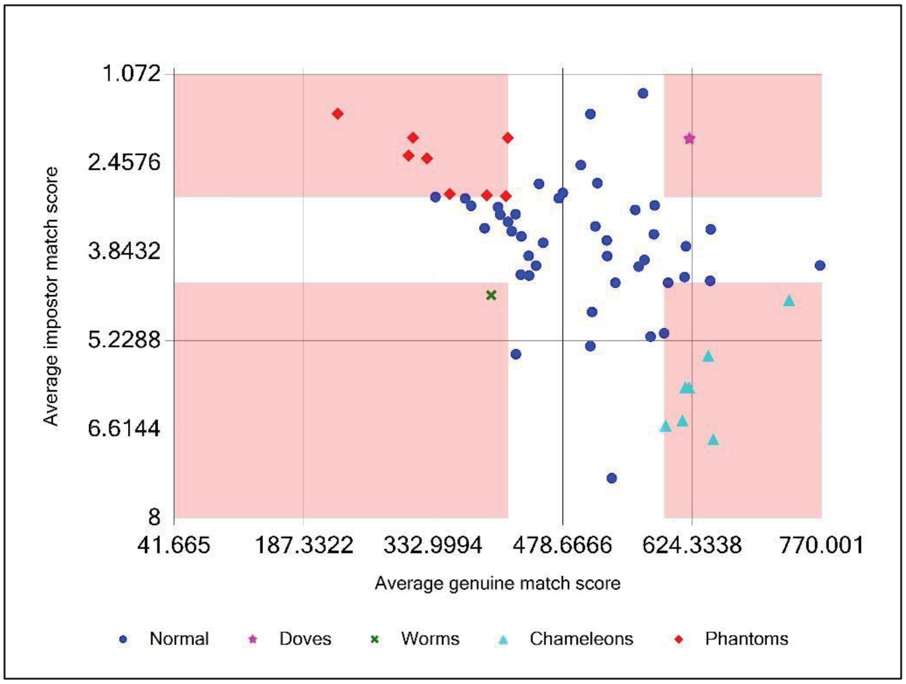

Figure 4.16 Zoo Plot Visit 5

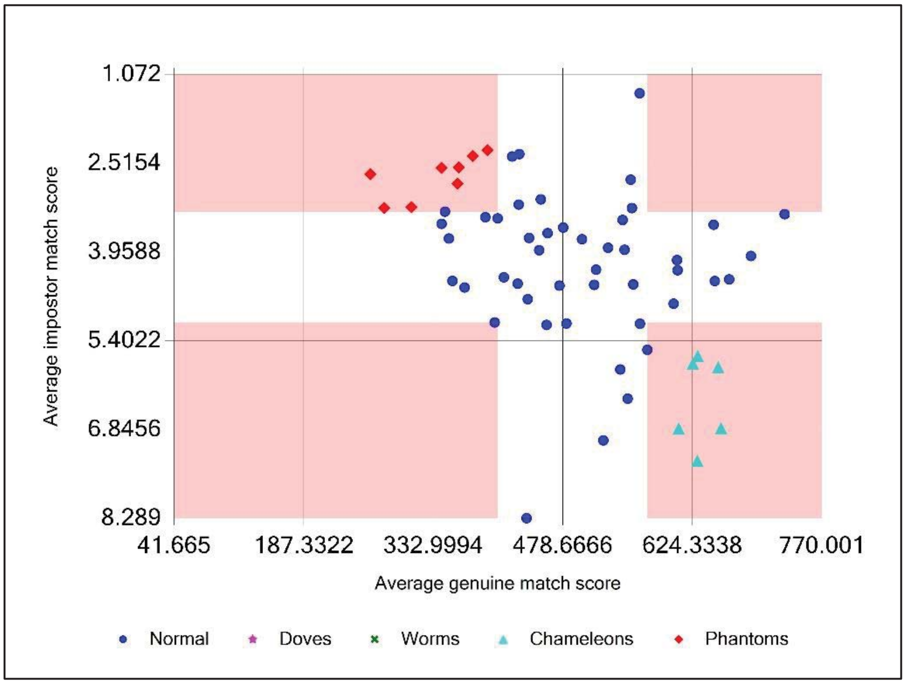

Figure 4.17 Zoo Plot Visit 6

These zoo plots above now gave more information as to the spread of the genuine and impostor scores. However, it is not possible to declare match score stability or instability at this point. Visit one and visit two appear to have individuals who performed worse than the rest of the population. These subjects are plotted on the left side on the plots, which corresponds to low genuine scores. However, with the current plots it is impossible to determine which subject irises are which particular data point. Who were these users? What is the relationship between a subject iris on one zoo and that same subject iris on another plot? In order to answer these questions, individual subject iris movement across the six visits was examined.

4.3.4 Individual Subject Iris Movement across Visits

Individual subject iris movement when examined with all visits scores plotted together was analyzed. In this section, each stability case will be explained and include an example. These cases are: intra-class durability, multi-class durability, intra-class fluctuation, and multi-class fluctuation.

Table 4.C *Subject Iris Movement Examples*

	Stability	Instability
Intra-Class	Figures 4.18-4.20	Figure 4.24
Multi-Class	Figure 4.22	Figure 4.26

4.3.4.1 Intra-Class Stability

Shown in Figure 4.18, subject 4-L (subject identification number-iris) exhibits intra-class stability. In intra-class stability, the subjects genuine and impostor scores are very similar. Additionally, points are classified under the same classification. In this case, subject 4-L is classified as normal for all visits.

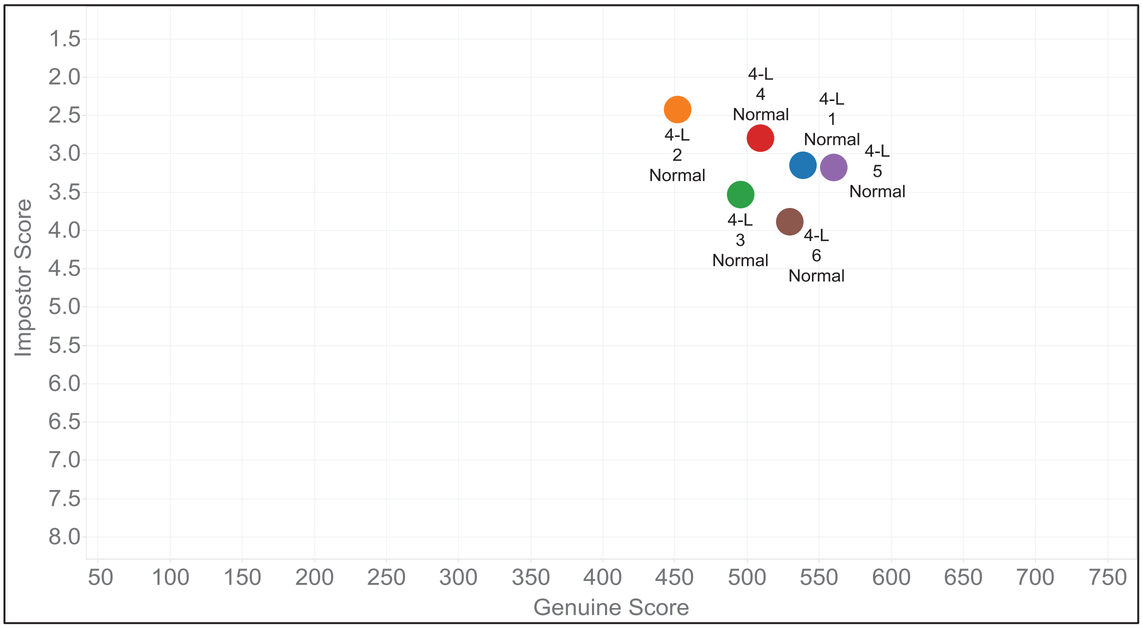

Figure 4.18 Subject 4-L: Intra-Class Stability

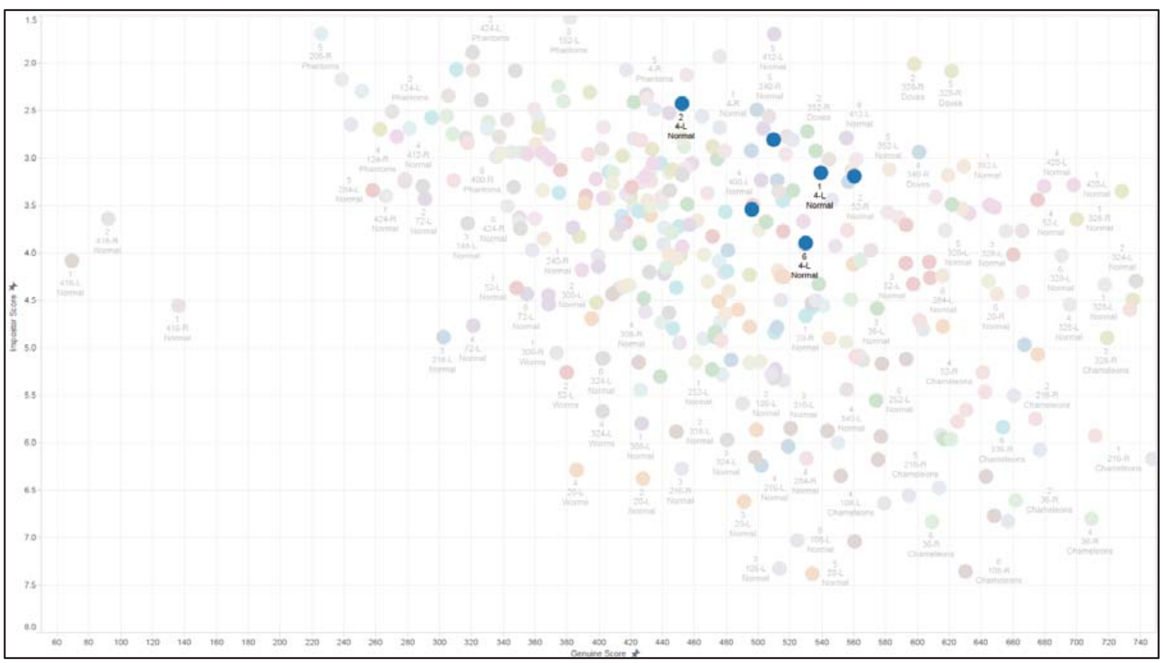

Figure 4.19 Subject 4-L: Total Zoo Plot by Subject

Table 4.D *SSI of Subject 4-L*

SID	SSI	Visit
4-L	0.11968	1-2
4-L	0.0595	1-3
4-L	0.04073	1-4
4-L	0.02883	1-5
4-L	0.01308	1-6
4-L	0.11968	2-1
4-L	0.0602	2-3
4-L	0.07895	2-4
4-L	0.14851	2-5
4-L	0.10665	2-6
4-L	0.0595	3-1
4-L	0.0602	3-2
4-L	0.01879	3-4
4-L	0.08833	3-5
4-L	0.04645	3-6
4-L	0.04073	4-1
4-L	0.07895	4-2
4-L	0.01879	4-3
4-L	0.06956	4-5
4-L	0.02773	4-6
4-L	0.02883	5-1
4-L	0.14851	5-2
4-L	0.08833	5-3
4-L	0.06956	5-4
4-L	0.04189	5-6
4-L	0.01308	6-1
4-L	0.10665	6-2
4-L	0.04645	6-3
4-L	0.02773	6-4
4-L	0.04189	6-5

Subject 36-R also exhibits intra-class stability (Figure 4.20). However, this is a different variation of intra-class stability then was shown in 4.3.4.1 with subject 4-L. In this case, the subject iris is durable to change, but could be considered a poor subject.

This is because the user classifications are all classified as chameleon. While the scores tend to be concentrated in the same area of the plot and the classifications are the same (chameleon in this case), the performance of this user is questionable. The user scores very high in both genuine and impostor scores. They may account for a lot of the error for the population, but the stability score index will be fairly low.

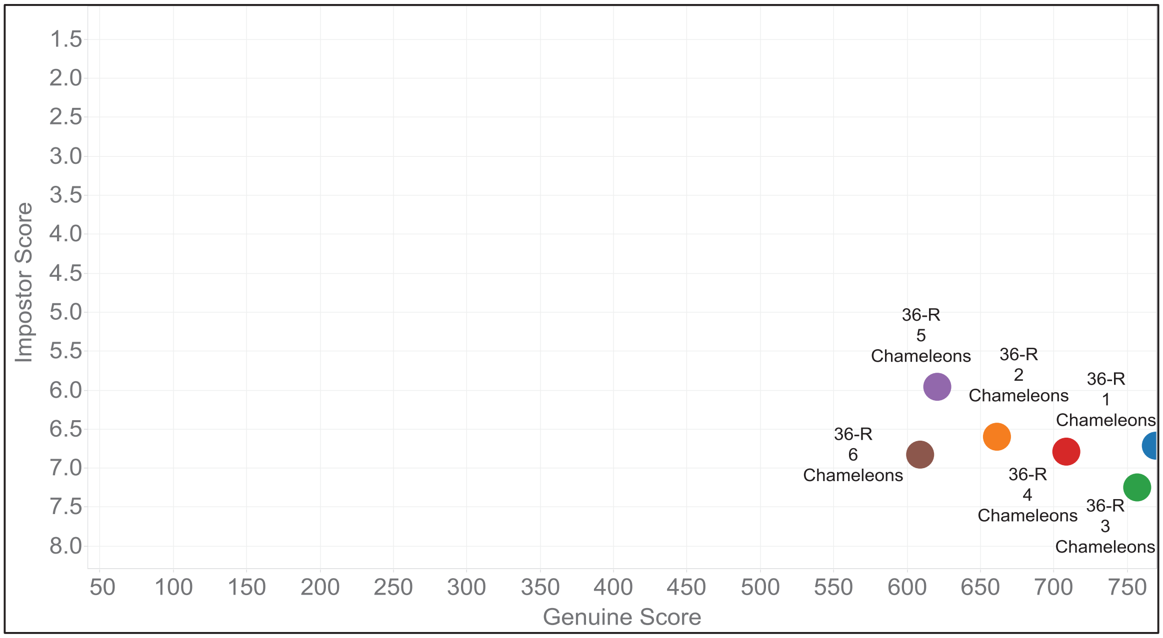

Figure 4.20 Subject 36-R: Intra-Class Stability

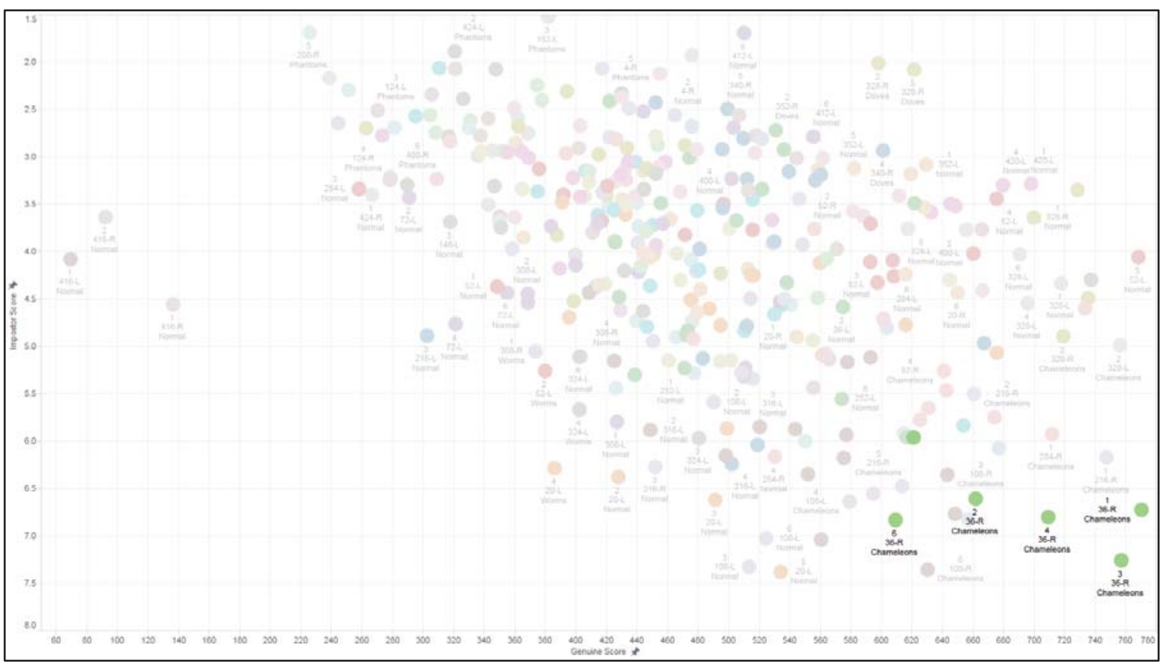

Figure 4.21 Subject 36-R: Total Zoo Plot by Subject

Table 4.E *SSI of Subject 36-R*

SID	SSI	Visit
36-R	0.14896	1-2
36-R	0.01809	1-3
36-R	0.08375	1-4
36-R	0.2048	1-5
36-R	0.22104	1-6
36-R	0.14896	2-1
36-R	0.13089	2-3
36-R	0.06521	2-4
36-R	0.05584	2-5
36-R	0.07208	2-6
36-R	0.01809	3-1
36-R	0.13089	3-2
36-R	0.06567	3-4
36-R	0.18673	3-5
36-R	0.20297	3-6
36-R	0.08375	4-1
36-R	0.06521	4-2
36-R	0.06567	4-3
36-R	0.12105	4-5
36-R	0.13729	4-6
36-R	0.2048	5-1
36-R	0.05584	5-2
36-R	0.18673	5-3
36-R	0.12105	5-4
36-R	0.01629	5-6
36-R	0.22104	6-1
36-R	0.07208	6-2
36-R	0.20297	6-3
36-R	0.13729	6-4
36-R	0.01629	6-5

4.3.4.2 Multi-Class Stability

Subject 168-L exhibits multi-class stability. Shown in Figure 4.22, all data points are clustered very closely together, just like intra-class stability. However, in this multi-class stability, there are multiple zoo classifications for the subject. In this example, Subject 168-L is classified as a normal on visits two through five and a phantom on visit one and visit six which are phantoms. Using a methodology which only examines if a subject changes classifications, this subject would be flagged. However, the genuine and impostor scores show very little deviation despite the change in classifications.

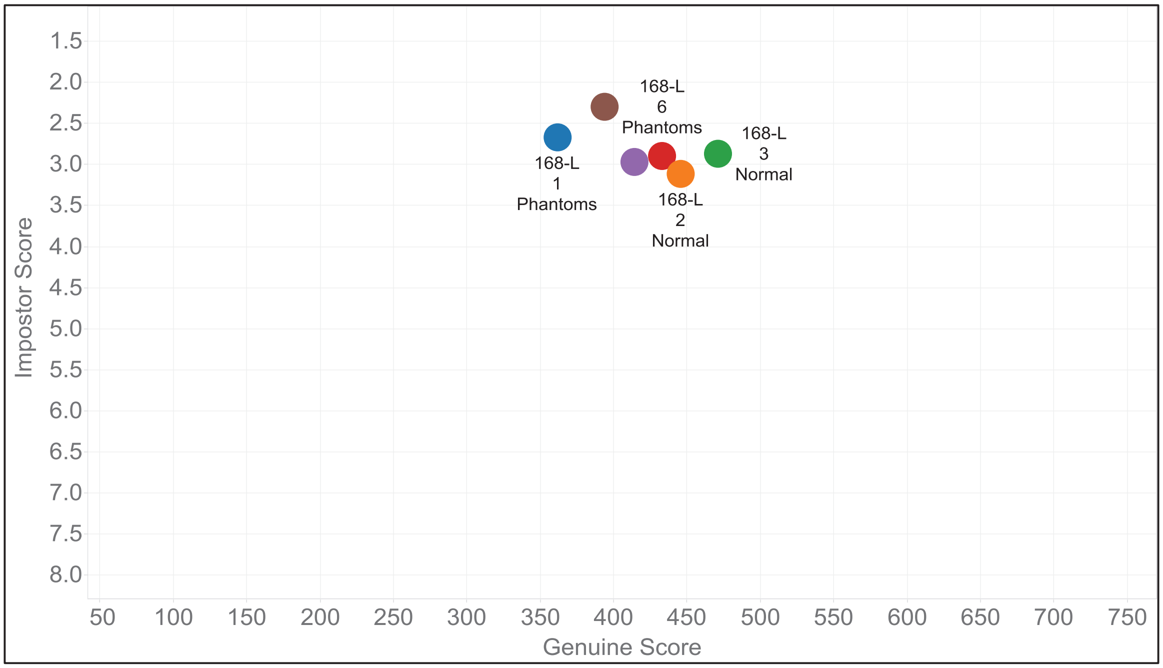

Figure 4.22 Subject 168-L: Multi-Class Stability

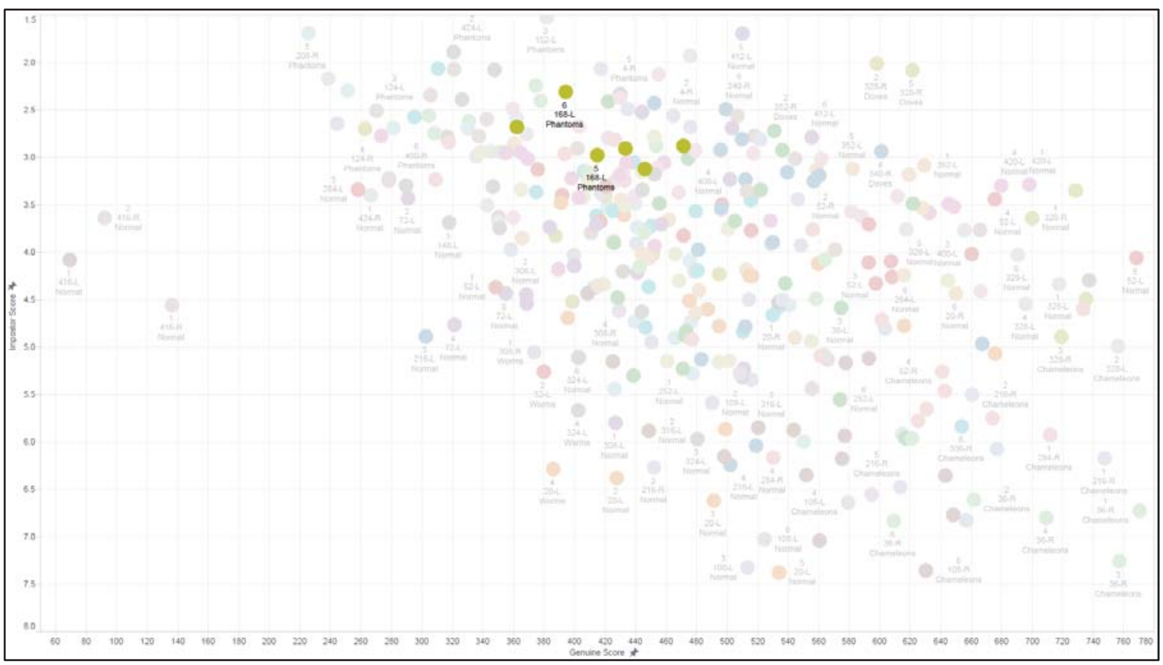

Figure 4.23 Subject 168-L: Total Zoo Plot by Subject

Table 4.F *SSI of Subject 168-L*

SID	SSI	Visit
168-L	0.1151	1-2
168-L	0.14988	1-3
168-L	0.09771	1-4
168-L	0.07231	1-5
168-L	0.04394	1-6
168-L	0.1151	2-1
168-L	0.03478	2-3
168-L	0.01739	2-4
168-L	0.04279	2-5
168-L	0.07117	2-6
168-L	0.14988	3-1
168-L	0.03478	3-2
168-L	0.05217	3-4
168-L	0.07757	3-5
168-L	0.10595	3-6
168-L	0.09771	4-1
168-L	0.01739	4-2
168-L	0.05217	4-3
168-L	0.0254	4-5
168-L	0.05378	4-6
168-L	0.07231	5-1
168-L	0.04279	5-2
168-L	0.07757	5-3
168-L	0.0254	5-4
168-L	0.02839	5-6
168-L	0.04394	6-1
168-L	0.07117	6-2
168-L	0.10595	6-3
168-L	0.05378	6-4
168-L	0.02839	6-5

4.3.4.3 Intra-Class Instability

Figure 4.24 depicts intra-class fluctuation. In this case, Subject 284-L was classified as a normal. However, the scores, and more specifically the genuine scores, are dispersed. This subjects match scores may be considered well behaved because they are classified as normal. Additionally, research examining if the subject changes classifications would also deem this subject acceptable. However, in regards to stability, they are not. The spread of the data, especially visit three, may impact system performance.

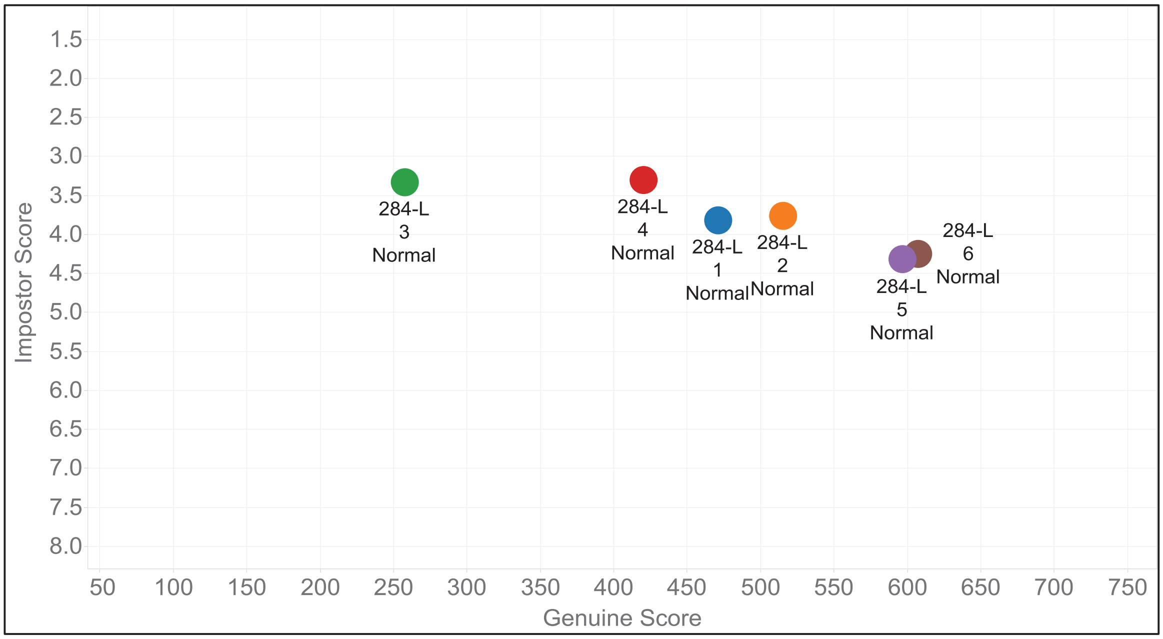

Figure 4.24 Subject 284-L: Intra-Class Instability

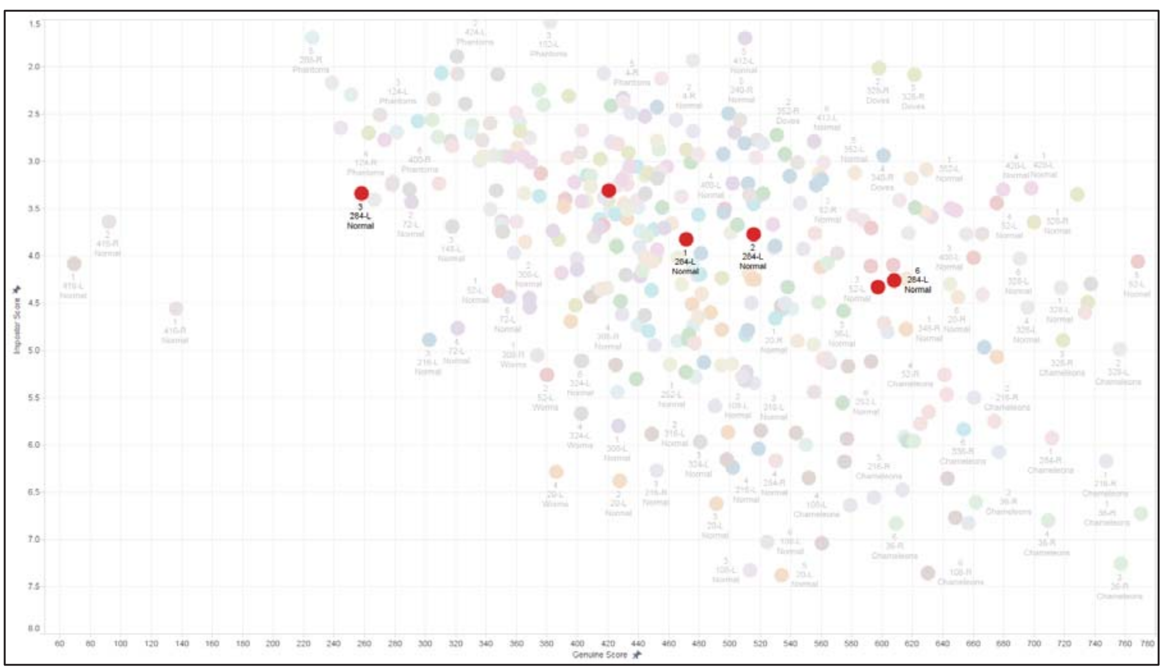

Figure 4.25 Subject 284-L: Total Zoo Plot by Subject

Table 4.G *SSI for Subject 284-R*

SID	SSI	Visit
284-R	0.05171	1-2
284-R	0.20663	1-3
284-R	0.24919	1-4
284-R	0.09496	1-5
284-R	0.11121	1-6
284-R	0.05171	2-1
284-R	0.15491	2-3
284-R	0.19747	2-4
284-R	0.04325	2-5
284-R	0.05949	2-6
284-R	0.20663	3-1
284-R	0.15491	3-2
284-R	0.04259	3-4
284-R	0.11167	3-5
284-R	0.09542	3-6
284-R	0.24919	4-1
284-R	0.19747	4-2
284-R	0.04259	4-3
284-R	0.15423	4-5
284-R	0.13798	4-6
284-R	0.09496	5-1
284-R	0.04325	5-2
284-R	0.11167	5-3
284-R	0.15423	5-4
284-R	0.01625	5-6
284-R	0.11121	6-1
284-R	0.05949	6-2
284-R	0.09542	6-3
284-R	0.13798	6-4
284-R	0.01625	6-5

4.3.4.4 Multi-Class Instability

Subject 416-R, shown in Figure 4.26, exhibits multi-class instability. In the case of Subject 416-R, there are two classifications associated, normal and chameleon. There is a great deal of spread between the data points, especially visit one and visit two with respect to visit three through six in this example. These users effect methodologies examining performance scores, changes in zoo classifications, as well as stability. These are the most inauspicious subjects that may cause the most harm to the system.

There were some interesting results from subject 416-R. Visit one and visit two had very poor genuine scores, but were grouped close together. Visit three, four, five, and six had higher genuine scores and were grouped closer together. Upon examination of the images, the subject had contacts for each visit. However, visit one and two appeared to have very different contact lenses then the other visits. The type and brand of contact was not collected in this study. However, it is apparent from Figure 4.26 that these different lenses impacted the stability of the iris greatly.

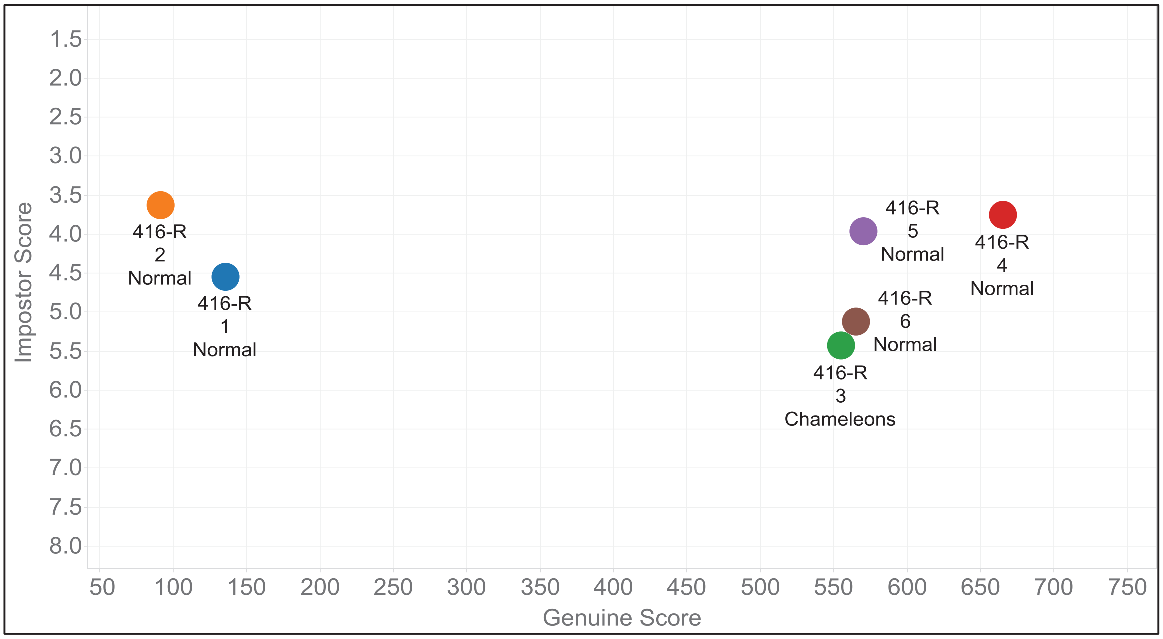

Figure 4.26 Subject 416-R: Multi-Class Instability

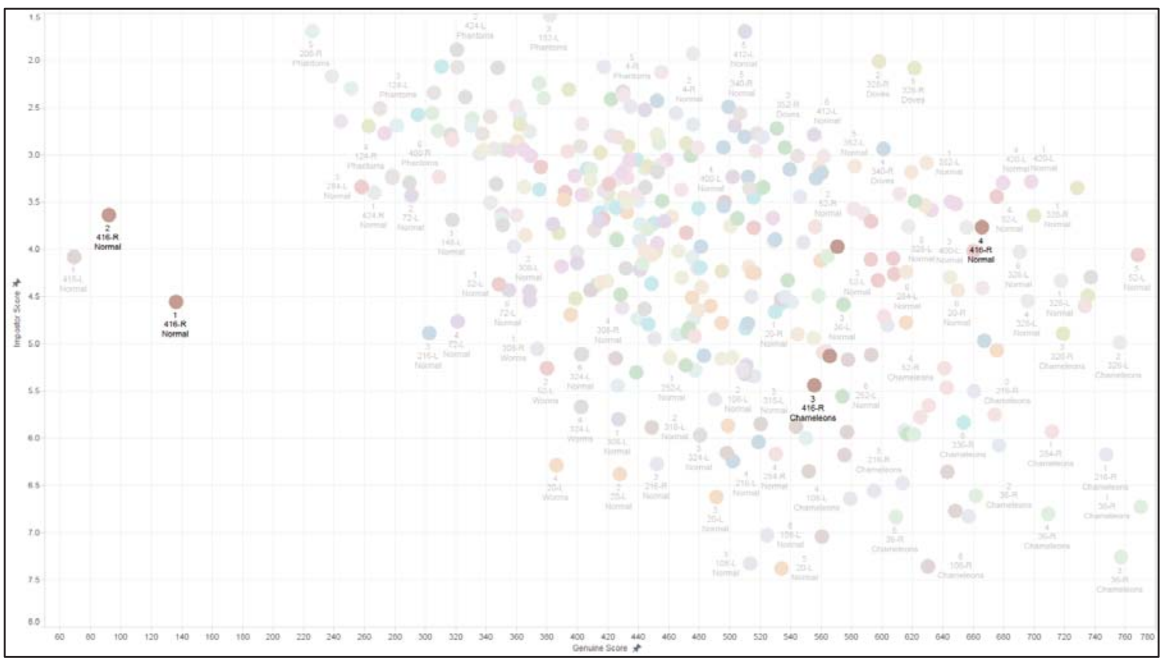

Figure 4.27 Subject 416-L: Total Zoo Plot by Subject

Table 4.H *SSI for Subject 416-R*

SID	SSI	Grouping
416-R	0.0606509	1-2
416-R	0.5757167	1-3
416-R	0.7269674	1-4
416-R	0.5965388	1-5
416-R	0.5896741	1-6
416-R	0.0606509	2-1
416-R	0.636358	2-3
416-R	0.7876044	2-4
416-R	0.6571762	2-5
416-R	0.6503146	2-6
416-R	0.5757167	3-1
416-R	0.636358	3-2
416-R	0.1512687	3-4
416-R	0.02092	3-5
416-R	0.0139646	3-6
416-R	0.7269674	4-1
416-R	0.7876044	4-2
416-R	0.1512687	4-3
416-R	0.1304287	4-5
416-R	0.1373058	4-6
416-R	0.5965388	5-1
416-R	0.6571762	5-2
416-R	0.02092	5-3
416-R	0.1304287	5-4
416-R	0.0070464	5-6
416-R	0.5896741	6-1
416-R	0.6503146	6-2
416-R	0.0139646	6-3
416-R	0.1373058	6-4
416-R	0.0070464	6-5

4.3.5 Basic Statistics and Normality Tests

Anderson-Darling normality tests were performed on each pair of stability score index (SSI) groupings (Visit 1 – Visit 2 and Visit 1 – Visit 3 for example), as well as all SSI combined. The results of the groupings set normality tests as well as other basic statistics can be found in Appendix D. A basic statistics output of all SSI combined is shown below along with associated interpretation of the Anderson-Darling normality test, mean, standard deviation, median, and the number of potential outliers in each grouping.

Anderson-Darling Normality Test Null and Alternative Hypothesis

H_0: The data are normally distributed

H_α: The data are not normal distributed

$\alpha = 0.05$

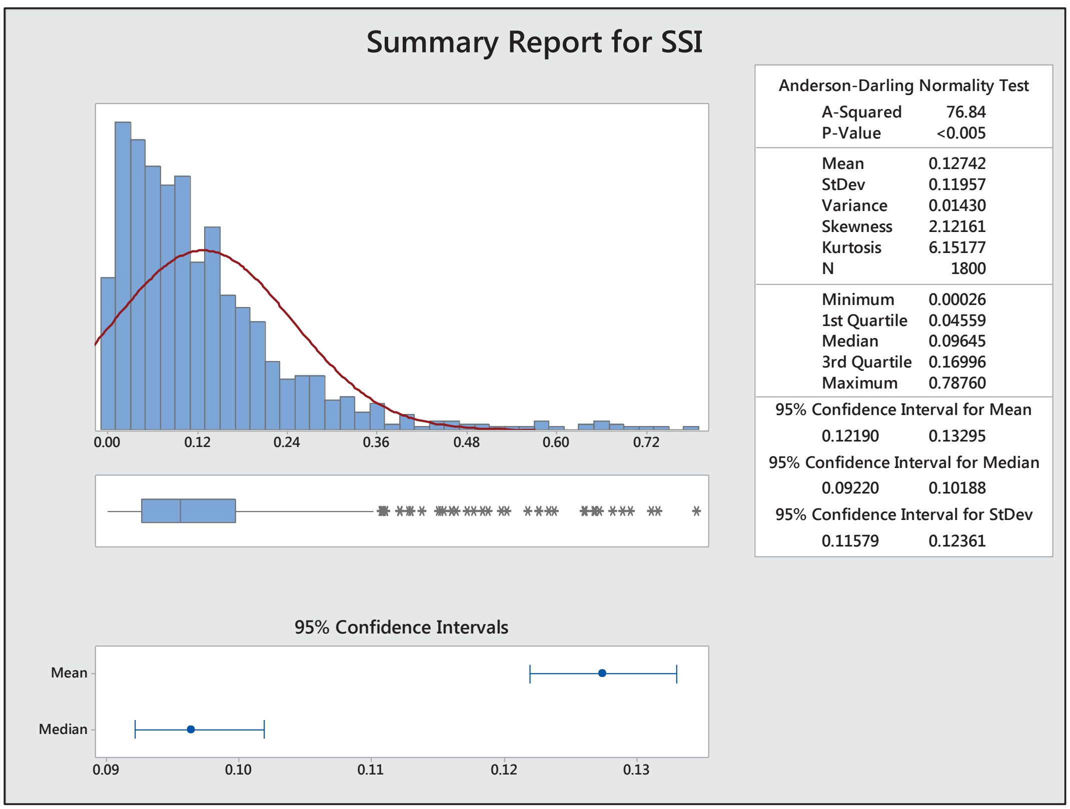

Figure 4.28 Summary Report for SSI (Grouped Visits)

Figure 4.28 shows there was a significant effect of the normality of the data between data collected from all six visits, A (1800) = 76.84, $p < 0.005$. The mean of the data is 0.12742, the standard deviation is 0.11957, and the median is 0.09645. There are several potential outliers that may significantly affect the results.

4.3.6 Kruskal-Wallis Non-Parametric Test for Stability

The Kruskal-Wallis non-parametric test is a test that examines non-normal data to determine if medians of different groupings exceed an established threshold. This test was chosen because the data is not normal, which is shown in the Anderson-Darling tests, and the median is not influenced by outliers. Shown in Eq. 4.1, the statistical software Minitab 17 was used to perform the test. An α of 0.05 was used to determine the significance. Groupings were created so that there was an all match case, with the exception of 1:1. For example, groupings included V1-V2, V4-V5, V3-V6, and V6-V1 but did not include V1-V1. The reason an exhaustive grouping analysis was performed was to determine the stability when comparing iris images examined in any order that the images were captured. Table C1 in Appendix C shows all subject iris SSI by grouping.

$$K = (\mathrm{N} - 1)\frac{\sum_{i=1}^{g} n_i(\bar{r}_i - \bar{r})^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(\bar{r}_{ij} - \bar{r})^2} \qquad \text{(Eq. 4.1)}$$

H_0 = There is no statistically significant difference between the medians of the stability scores

H_α = There is a statistically significant difference between the medians of the stability scores

$\alpha = 0.05$

Table 4.I *Kruskal-Wallis Non-Parametric Test Results*

Grouping	N	Median	Ave Rank	Z
1-2	60	0.08913	784.3	-1.76
1-3	60	0.09153	896.4	-0.06
1-4	60	0.09749	973.1	1.10
1-5	60	0.09920	956.8	0.85
1-6	60	0.12357	1009.5	1.65
2-1	60	0.08913	784.3	-1.76
2-3	60	0.09645	940.1	0.60
2-4	60	0.09931	927.1	0.40
2-5	60	0.08158	889.5	-0.17
2-6	60	0.08902	866.0	-0.52
3-1	60	0.09153	896.4	-0.06
3-2	60	0.09645	940.1	0.60
3-4	60	0.09554	879.7	-0.32
3-5	60	0.10194	941.0	0.61
3-6	60	0.09233	899.9	-0.01
4-1	60	0.09749	973.1	1.10
4-2	60	0.09931	927.1	0.40
4-3	60	0.09554	879.7	-0.32
4-5	60	0.12208	904.4	0.06
4-6	60	0.09622	879.6	-0.32
5-1	60	0.09920	956.8	0.85
5-2	60	0.08158	889.5	-0.17
5-3	60	0.10194	941.0	0.61
5-4	60	0.12208	904.4	0.06
5-6	60	0.06957	760.2	-2.13
6-1	60	0.12357	1009.5	1.65
6-2	60	0.08902	866.0	-0.52
6-3	60	0.09233	899.9	-0.01
6-4	60	0.09622	879.6	-0.32
6-5	60	0.06957	760.2	-2.13
Overall	1800		900.5	
H = 26.49	DF = 29	P = 0.599		
H = 26.49	DF = 29	P = 0.599 (adjusted for ties)		

Table 4.I shows the results of the Kruskal-Wallis test. There was not a statistically significant difference between the median of the groupings (H(29) = 22.19, p = 0.599), with a mean rank of 784.3 for grouping 1-2, 896.4 for grouping 1-3, 973.1 for grouping

1-4, 956.8 for grouping 1-5, 1009.5 for grouping 1-6, 784.3 for grouping 2-1, 940.1 for grouping 2-3, 927.1 for grouping 2-4, 889.5 for grouping 2-5, 866.0 for grouping 2-6, 896.4 for grouping 3-1, 940.1 for grouping 3-2, 879.7 for grouping 3-4, 941.0 for grouping 3-5, 899.9 for grouping 3-6, 973.1 for grouping 4-1, 927.1 for grouping 4-2, 879.7 for grouping 4-3, 904.4 for grouping 4-5, 879.6 for grouping 4-6, 956.8 for grouping 5-1, 889.5 for grouping 5-2, 941.0 for grouping 5-3, 904.4 for grouping 5-4, 760.2 for grouping 5-6, 1009.5 for grouping 6-1, 866.0 for grouping 6-2, 899.9 for grouping 6-3, 879.6 for grouping 6-4, and 760.2 for grouping 6-5.

With the evidence gathered, $p = 0.812$ is greater than the established α (0.05). Therefore, this data fails to reject the null hypothesis that the median stability scores are equal and shows stability of the iris in the month range across six months.

CHAPTER 5. CONCLUSIONS, RECOMMENDATIONS, AND FUTURE WORK

This study examined the stability of the iris over the course of six visits, each spanning a month between visits. Stability of the iris has been greatly contested (Baker et al., 2013; Grother et al., 2013) over a multitude of time spans with no real definitive answer found. Intra-visit stability has been found, however as well as across multiple visits with one month between data collection periods found in this research (Anydiewu et al., 2015; Bartley et al., 2015; Boyle et al., 2015; Brown et al., 2015; Fevig et al., 2015; Herrmann et al., 2015).

5.1 Conclusions

The results of this research shows statistical stability of the iris within the month duration range. The statistical tests and summaries in Chapter Four show that while individual scores may change slightly, the overall stability score index (SSI) do not change. These results are consistent when comparing images taken from sequential visits as well as non-sequential visits. These results show that there are changes, however, in scores. These changes could be due to many factors. Taking into account all known and unknown factors this dataset of iris images can be considered statistically stable within the month duration time frame.

5.2 Future Work for Research

To continue the advancement of this and related research, several additional questions and observations are considered for further investigation.

1. This study focused on iris images collected in the month duration time frame. In order to show statistical stability of the iris overall, long durations should be examined. The next logical step would be the year duration.
2. Subjects in this study were predominantly Caucasians ages 18-35. A replication of the study with a wider, more diverse demographic set may yield different results.
3. Only one matching algorithm and sensor were used in this study. Paone and Flynn (2011) have shown that different iris matching algorithms yield different zoo menagerie classifications. Different algorithms or sensors may yield different results for this study as well.
4. The stability score index was used for this study (iris) and fingerprint (O'Connor, 2013). The stability score index may be applicable to a wider set of modalities and research applications.
5. Are quality metrics of the iris stable over time? Time in this case can be days, weeks, months, years, or life of the user. Instead of focusing of the final result of match scores, how are the individual metrics affected by time?
6. Are there some individuals which are more stable than others, or are there individuals who are less stable than others?
7. What is the impact of different kinds of contact lenses in iris recognition? What are the different lenses impact on the stability score index of the subject irises?

5.3 Observations for Practice

The recommendations in this section are based on the research in 5.2 being completed. The stability of the iris in regards to different durations may have some applicability for implementation of iris recognition. Stability is critical in biometrics. The iris may be stable, but only up to a certain duration length. Stability does not, however, inherently mean physiological aging of the iris. Stability could be affected by a number of factors. Subjects may need to reenroll or undergo template updating as interactions occur. If a specific time range can be defined for stability, test administrators would be able to set the appropriate time thresholds for reenrolling or template updating. This will keep the system more robust. Additionally, the general population irises may be stable for, but may not be for some individuals. Instead of subjecting all users to a reenroll process, only those individuals who exhibit unstable iris characteristics would need to undergo reenrollment, saving time and money for all parties.

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APPENDICES

Appendix A: Subject Iris Images Selected for Analysis

Table A1 *Number of Images per Subject per Visit*

	Visit						
Subject ID	2	3	4	5	6	7	8
4	45	40	40	40	40	40	42
20	8	40	40	42	44	42	42
36	6	44	41	45	42	41	44
52	15	47	43	40	45	44	40
72	13	28	29	31	12	36	31
108	13	43	41	41	46	44	40
124	37	45	40	41	49	40	40
136	72	40	42	42	46	42	40
152	0	20	24	24	20	20	20
168	0	40	40	40	40	42	40
208	18	45	43	41	42	42	42
216	18	41	40	43	47	40	40
240	4	41	44	44	43	43	45
252	22	44	45	42	40	44	40
280	40	40	40	0	40	40	42
284	40	40	50	42	42	42	42
308	44	41	44	43	43	45	47
316	0	41	41	40	40	42	40
320	14	41	41	41	40	40	41
324	0	24	38	42	43	42	42
328	0	42	43	40	43	43	46
336	11	43	50	41	44	43	45
340	40	40	42	42	40	40	40
348	44	45	44	41	40	40	42
352	9	42	42	40	42	43	40
384	2	24	28	43	46	45	42
400	40	40	40	44	40	42	40
412	15	44	44	43	42	45	44
416	40	40	42	40	40	40	40
420	43	40	46	41	46	45	40
424	44	47	41	44	41	43	43
432	18	43	45	43	44	45	50
436	44	44	40	42	40	46	40

Table A2 *Number of Images per Subject Iris per Visit*

Subject ID	Visit						
	2	3	4	5	6	7	8
4-L	22	20	20	20	20	20	20
20-L	4	20	25	22	22	21	21
36-L	3	25	25	25	25	25	26
52-L	13	25	21	20	21	20	20
72-L	9	19	15	18	12	19	14
108-L	7	25	21	21	24	24	20
124-L	24	25	20	21	25	20	20
136-L	46	20	22	21	24	21	20
152-L	0	20	24	24	20	20	20
168-L	0	20	20	20	20	21	20
208-L	9	22	21	21	21	21	20
216-L	9	21	20	23	23	20	20
240-L	2	21	25	24	23	23	24
252-L	10	24	23	21	20	21	20
280-L	20	20	20	0	20	20	20
284-L	20	20	21	22	25	22	20
308-L	22	22	24	21	23	23	25
316-L	0	21	21	20	20	22	20
320-L	7	21	20	21	20	20	21
324-L	0	14	25	26	25	24	22
328-L	0	25	24	20	25	23	24
336-L	6	25	25	21	23	28	23
340-L	20	20	21	21	20	20	20
348-L	24	25	24	21	20	20	21
352-L	3	20	20	20	21	21	20
384-L	1	16	16	23	25	26	24
400-L	20	20	20	23	20	20	20
412-L	9	24	25	25	25	25	23
416-L	20	20	20	20	20	20	20
420-L	21	20	21	21	23	24	21
424-L	24	25	20	24	21	23	23
432-L	9	24	22	20	22	23	25
436-L	21	22	20	20	20	21	20
4-R	23	20	20	20	20	20	22
20-R	4	20	15	20	22	21	21

36-R	3	19	16	20	17	16	18
52-R	2	22	22	20	24	24	20
72-R	4	9	14	13	0	17	17
108-R	6	18	20	20	22	20	20
124-R	13	20	20	20	24	20	20
136-R	26	20	20	21	22	21	20
168-R	0	20	20	20	20	21	20
208-R	9	23	22	20	21	21	22
216-R	9	20	20	20	24	20	20
240-R	2	20	19	20	20	20	21
252-R	12	20	22	21	20	23	20
280-R	20	20	20	0	20	20	22
284-R	20	20	29	20	17	20	22
308-R	22	19	20	22	20	22	22
316-R	0	20	20	20	20	20	20
320-R	7	20	21	20	20	20	20
324-R	0	10	13	16	18	18	20
328-R	0	17	19	20	18	20	22
336-R	5	18	25	20	21	15	22
340-R	20	20	21	21	20	20	20
348-R	20	20	20	20	20	20	21
352-R	6	22	22	20	21	22	20
384-R	1	8	12	20	21	19	18
400-R	20	20	20	21	20	22	20
412-R	6	20	19	18	17	20	21
416-R	20	20	22	20	20	20	20
420-R	22	20	25	20	23	21	19
424-R	20	22	21	20	20	20	20
432-R	9	19	23	23	22	22	25
436-R	23	22	20	22	20	25	20

Table A3 *Number of Images per Subject Iris per Visit Final Pool*

Subject ID	Visit 3	4	5	6	7	8
4-L	20	20	20	20	20	20
20-L	20	25	22	22	21	21
36-L	25	25	25	25	25	26
52-L	25	21	20	21	20	20
72-L	19	15	18	12	19	14
108-L	25	21	21	24	24	20
124-L	25	20	21	25	20	20
136-L	20	22	21	24	21	20
152-L	20	24	24	20	20	20
168-L	20	20	20	20	21	20
208-L	22	21	21	21	21	20
216-L	21	20	23	23	20	20
240-L	21	25	24	23	23	24
252-L	24	23	21	20	21	20
284-L	20	21	22	25	22	20
308-L	22	24	21	23	23	25
316-L	21	21	20	20	22	20
320-L	21	20	21	20	20	21
324-L	14	25	26	25	24	22
328-L	25	24	20	25	23	24
336-L	25	25	21	23	28	23
340-L	20	21	21	20	20	20
348-L	25	24	21	20	20	21
352-L	20	20	20	21	21	20
384-L	16	16	23	25	26	24
400-L	20	20	23	20	20	20
412-L	24	25	25	25	25	23
416-L	20	20	20	20	20	20
420-L	20	21	21	23	24	21
424-L	25	20	24	21	23	23
432-L	24	22	20	22	23	25
436-L	22	20	20	20	21	20
4-R	20	20	20	20	20	22
20-R	20	15	20	22	21	21
36-R	19	16	20	17	16	18

52-R	22	22	20	24	24	20
108-R	18	20	20	22	20	20
124-R	20	20	20	24	20	20
136-R	20	20	21	22	21	20
168-R	20	20	20	20	21	20
208-R	23	22	20	21	21	22
216-R	20	20	20	24	20	20
240-R	20	19	20	20	20	21
252-R	20	22	21	20	23	20
284-R	20	29	20	17	20	22
308-R	19	20	22	20	22	22
316-R	20	20	20	20	20	20
320-R	20	21	20	20	20	20
328-R	17	19	20	18	20	22
336-R	18	25	20	21	15	22
340-R	20	21	21	20	20	20
348-R	20	20	20	20	20	21
352-R	22	22	20	21	22	20
400-R	20	20	21	20	22	20
412-R	20	19	18	17	20	21
416-R	20	22	20	20	20	20
420-R	20	25	20	23	21	19
424-R	22	21	20	20	20	20
432-R	19	23	23	22	22	25
436-R	22	20	22	20	25	20

Table A4 *Locator Number Associated with SID, Iris, and Visit*

Locator Number	SID	Modality Subtype	Visit
2660066	4	L	1
2660070	4	L	1
2660086	4	L	1
2660170	20	L	1
2660194	20	L	1
2660202	20	L	1
2660328	36	L	1
2660332	36	L	1
2660338	36	L	1
2660406	52	L	1
2660420	52	L	1
2660432	52	L	1
2660596	72	L	1
2660606	72	L	1
2660610	72	L	1
2661050	108	L	1
2661052	108	L	1
2661060	108	L	1
2661180	124	L	1
2661194	124	L	1
2661198	124	L	1
2661294	136	L	1
2661298	136	L	1
2661306	136	L	1
2661350	152	L	1
2661362	152	L	1
2661366	152	L	1
2661518	168	L	1
2661530	168	L	1
2661534	168	L	1
2661836	208	L	1
2661860	208	L	1
2661882	208	L	1
2661926	216	L	1
2661934	216	L	1
2661942	216	L	1

2662164	240	L	1
2662172	240	L	1
2662184	240	L	1
2662320	252	L	1
2662324	252	L	1
2662328	252	L	1
2662756	284	L	1
2662772	284	L	1
2662780	284	L	1
2663166	308	L	1
2663192	308	L	1
2663200	308	L	1
2663344	316	L	1
2663356	316	L	1
2663366	316	L	1
2663420	320	L	1
2663432	320	L	1
2663440	320	L	1
2663518	324	L	1
2663520	324	L	1
2663528	324	L	1
2663544	328	L	1
2663548	328	L	1
2663578	328	L	1
2663626	336	L	1
2663648	336	L	1
2663654	336	L	1
2663710	340	L	1
2663718	340	L	1
2663722	340	L	1
2663786	348	L	1
2663794	348	L	1
2663824	348	L	1
2663892	352	L	1
2663900	352	L	1
2663912	352	L	1
2664304	384	L	1
2664324	384	L	1
2664332	384	L	1

2664348	400	L	1
2664368	400	L	1
2664392	400	L	1
2664436	412	L	1
2664464	412	L	1
2664466	412	L	1
2664524	416	L	1
2664544	416	L	1
2664548	416	L	1
2664616	420	L	1
2664620	420	L	1
2664628	420	L	1
2664684	424	L	1
2664704	424	L	1
2664712	424	L	1
2664772	432	L	1
2664778	432	L	1
2664804	432	L	1
2664878	436	L	1
2664888	436	L	1
2664896	436	L	1
2660072	4	R	1
2660076	4	R	1
2660104	4	R	1
2660200	20	R	1
2660204	20	R	1
2660216	20	R	1
2660314	36	R	1
2660318	36	R	1
2660348	36	R	1
2660408	52	R	1
2660418	52	R	1
2660434	52	R	1
2661054	108	R	1
2661062	108	R	1
2661098	108	R	1
2661196	124	R	1
2661200	124	R	1
2661220	124	R	1

2661268	136	R	1
2661276	136	R	1
2661288	136	R	1
2661520	168	R	1
2661528	168	R	1
2661552	168	R	1
2661838	208	R	1
2661842	208	R	1
2661872	208	R	1
2661928	216	R	1
2661958	216	R	1
2661966	216	R	1
2662150	240	R	1
2662166	240	R	1
2662186	240	R	1
2662334	252	R	1
2662342	252	R	1
2662352	252	R	1
2662754	284	R	1
2662766	284	R	1
2662786	284	R	1
2663172	308	R	1
2663194	308	R	1
2663214	308	R	1
2663330	316	R	1
2663346	316	R	1
2663358	316	R	1
2663408	320	R	1
2663422	320	R	1
2663454	320	R	1
2663554	328	R	1
2663558	328	R	1
2663572	328	R	1
2663630	336	R	1
2663642	336	R	1
2663646	336	R	1
2663720	340	R	1
2663736	340	R	1
2663748	340	R	1

2663808	348	R	1
2663828	348	R	1
2663836	348	R	1
2663882	352	R	1
2663902	352	R	1
2663922	352	R	1
2664350	400	R	1
2664362	400	R	1
2664390	400	R	1
2664430	412	R	1
2664448	412	R	1
2664482	412	R	1
2664542	416	R	1
2664550	416	R	1
2664554	416	R	1
2664606	420	R	1
2664622	420	R	1
2664642	420	R	1
2664686	424	R	1
2664700	424	R	1
2664706	424	R	1
2664812	432	R	1
2664816	432	R	1
2664820	432	R	1
2664874	436	R	1
2664894	436	R	1
2664898	436	R	1
2665244	4	L	2
2665264	4	L	2
2665272	4	L	2
2665374	20	L	2
2665380	20	L	2
2665388	20	L	2
2665520	36	L	2
2665524	36	L	2
2665538	36	L	2
2665582	52	L	2
2665586	52	L	2
2665590	52	L	2

2665672	72	L	2
2665676	72	L	2
2665696	72	L	2
2666054	108	L	2
2666062	108	L	2
2666070	108	L	2
2666206	124	L	2
2666234	124	L	2
2666238	124	L	2
2666296	136	L	2
2666304	136	L	2
2666312	136	L	2
2666392	152	L	2
2666404	152	L	2
2666406	152	L	2
2666444	168	L	2
2666452	168	L	2
2666484	168	L	2
2666710	208	L	2
2666722	208	L	2
2666726	208	L	2
2666816	216	L	2
2666828	216	L	2
2666836	216	L	2
2667042	240	L	2
2667060	240	L	2
2667064	240	L	2
2667134	252	L	2
2667148	252	L	2
2667160	252	L	2
2667470	284	L	2
2667474	284	L	2
2667498	284	L	2
2667830	308	L	2
2667838	308	L	2
2667860	308	L	2
2668004	316	L	2
2668016	316	L	2
2668032	316	L	2

2668096	320	L	2
2668104	320	L	2
2668120	320	L	2
2668170	324	L	2
2668176	324	L	2
2668182	324	L	2
2668262	328	L	2
2668270	328	L	2
2668278	328	L	2
2668346	336	L	2
2668348	336	L	2
2668362	336	L	2
2668446	340	L	2
2668454	340	L	2
2668466	340	L	2
2668520	348	L	2
2668540	348	L	2
2668552	348	L	2
2668606	352	L	2
2668610	352	L	2
2668626	352	L	2
2668912	384	L	2
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2676766	136	L	5
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2681932	436	L	6
2681940	436	L	6
2679244	4	R	6
2679260	4	R	6
2679262	4	R	6
2679320	20	R	6
2679344	20	R	6
2679356	20	R	6
2679414	36	R	6
2679422	36	R	6
2679448	36	R	6
2679516	52	R	6
2679520	52	R	6
2679532	52	R	6
2679630	108	R	6
2679634	108	R	6
2679646	108	R	6

2679710	124	R	6
2679722	124	R	6
2679754	124	R	6
2679802	136	R	6
2679814	136	R	6
2679818	136	R	6
2679966	168	R	6
2679970	168	R	6
2679982	168	R	6
2680034	208	R	6
2680070	208	R	6
2680074	208	R	6
2680122	216	R	6
2680134	216	R	6
2680154	216	R	6
2680208	240	R	6
2680212	240	R	6
2680230	240	R	6
2680300	252	R	6
2680308	252	R	6
2680328	252	R	6
2680468	284	R	6
2680482	284	R	6
2680488	284	R	6
2680540	308	R	6
2680552	308	R	6
2680556	308	R	6
2680638	316	R	6
2680646	316	R	6
2680670	316	R	6
2680730	320	R	6
2680738	320	R	6
2680746	320	R	6
2680870	328	R	6
2680882	328	R	6
2680890	328	R	6
2680984	336	R	6
2681000	336	R	6
2681004	336	R	6

2681056	340	R	6
2681072	340	R	6
2681076	340	R	6
2681140	348	R	6
2681156	348	R	6
2681160	348	R	6
2681216	352	R	6
2681228	352	R	6
2681252	352	R	6
2681380	400	R	6
2681404	400	R	6
2681416	400	R	6
2681474	412	R	6
2681486	412	R	6
2681496	412	R	6
2681572	416	R	6
2681580	416	R	6
2681592	416	R	6
2681632	420	R	6
2681648	420	R	6
2681652	420	R	6
2681712	424	R	6
2681716	424	R	6
2681738	424	R	6
2681810	432	R	6
2681830	432	R	6
2681838	432	R	6
2681898	436	R	6
2681910	436	R	6
2681938	436	R	6

Appendix B: Table of Zoo Animals

Table B1 *Table of Zoo Animals*

Visit	SID	Zoo Classification	Genuine Score	Impostor Score
1	4-L	Normal	539.1667	3.1507
1	20-L	Chameleons	547.5000	8.0866
1	36-L	Normal	621.5000	3.4840
1	52-L	Normal	348.1667	4.3653
1	72-L	Normal	383.5000	3.7288
1	108-L	Normal	508.1667	5.2731
1	124-L	Normal	401.6667	2.9021
1	148-L	Normal	452.1667	3.1733
1	152-L	Normal	475.6667	1.9247
1	168-L	Phantoms	362.0000	2.6742
1	208-L	Phantoms	294.8333	2.5687
1	216-L	Chameleons	667.0000	4.9623
1	240-L	Normal	498.6667	5.8625
1	252-L	Normal	470.8333	5.2241
1	284-L	Normal	471.1667	3.8192
1	308-L	Normal	426.6667	5.7928
1	316-L	Normal	408.3333	4.4294
1	320-L	Normal	389.1667	4.1751
1	324-L	Normal	443.8333	4.6252
1	328-L	Normal	717.3333	4.3314
1	336-L	Phantoms	337.8333	2.9416
1	340-L	Normal	465.5000	4.8983
1	348-L	Normal	536.1667	4.4972
1	352-L	Normal	629.0000	3.0810
1	384-L	Phantoms	304.3333	2.5556
1	400-L	Normal	592.6667	3.7006
1	412-L	Normal	444.0000	2.5179
1	416-L	Normal	69.0000	4.0772
1	420-L	Normal	697.8333	3.2806
1	424-L	Phantoms	347.3333	2.0734
1	432-L	Normal	419.8333	3.4030
1	436-L	Normal	414.1667	3.6083
1	4-R	Normal	475.6667	2.6742
1	20-R	Normal	544.3333	4.8964
1	36-R	Chameleons	770.0000	6.7213

1	52-R	Normal	476.6667	4.9171
1	108-R	Chameleons	576.8333	5.9303
1	124-R	Normal	434.0000	3.0471
1	136-R	Phantoms	108.1667	1.0734
1	168-R	Normal	425.1667	3.8757
1	208-R	Phantoms	251.0000	2.2900
1	216-R	Chameleons	747.1667	6.1676
1	240-R	Normal	365.5000	3.8475
1	252-R	Phantoms	330.5000	2.6121
1	284-R	Chameleons	711.5000	5.9228
1	308-R	Worms	373.3333	5.0490
1	316-R	Normal	410.6667	3.7928
1	320-R	Normal	439.0000	3.4068
1	328-R	Normal	699.6667	3.6384
1	336-R	Normal	446.3333	4.7891
1	340-R	Normal	495.5000	2.9171
1	348-R	Normal	615.6667	4.7702
1	352-R	Normal	521.6667	3.3371
1	400-R	Normal	516.8333	3.3879
1	412-R	Normal	478.5000	4.1996
1	416-R	Normal	136.0000	4.5518
1	420-R	Doves	561.5000	3.0094
1	424-R	Normal	266.1667	3.3974
1	432-R	Normal	501.1667	5.1412
1	436-R	Normal	439.5000	3.4802
2	4-L	Normal	452.0000	2.4218
2	20-L	Normal	427.5000	6.3748
2	36-L	Normal	425.5000	3.8983
2	52-L	Worms	379.6667	5.2542
2	72-L	Normal	290.6667	3.4256
2	108-L	Normal	490.0000	5.5838
2	124-L	Phantoms	337.1667	2.7721
2	148-L	Normal	444.3333	3.3371
2	152-L	Phantoms	376.3333	1.3710
2	168-L	Normal	445.8333	3.1168
2	208-L	Normal	438.6667	3.0490
2	216-L	Chameleons	518.6667	6.0358
2	240-L	Normal	487.1667	4.5951
2	252-L	Normal	473.0000	4.8286
2	284-L	Normal	515.5000	3.7665
2	308-L	Normal	368.1667	4.4426

2	316-L	Normal	448.5000	5.8795
2	320-L	Normal	350.0000	3.6252
2	324-L	Normal	737.0000	4.2919
2	328-L	Chameleons	756.0000	4.9831
2	336-L	Normal	444.0000	3.1450
2	340-L	Normal	477.1667	5.2768
2	348-L	Normal	358.0000	3.9661
2	352-L	Normal	619.0000	3.1770
2	384-L	Phantoms	308.0000	2.7401
2	400-L	Normal	416.6667	3.6723
2	412-L	Normal	429.6667	2.3277
2	416-L	Worms	41.6667	5.3578
2	420-L	Normal	632.3333	3.5800
2	424-L	Phantoms	320.5000	1.8832
2	432-L	Normal	451.0000	4.0188
2	436-L	Normal	450.0000	3.7175
2	4-R	Normal	464.5000	2.5556
2	20-R	Normal	479.1667	4.6384
2	36-R	Chameleons	661.5000	6.6045
2	52-R	Normal	555.8333	3.7571
2	108-R	Normal	497.8333	6.1507
2	124-R	Phantoms	355.0000	2.9492
2	136-R	Doves	517.0000	2.9548
2	168-R	Normal	432.5000	3.5047
2	208-R	Normal	349.8333	3.6723
2	216-R	Chameleons	660.3333	5.4972
2	240-R	Normal	430.1667	3.4444
2	252-R	Normal	408.5000	3.1488
2	284-R	Chameleons	673.8333	5.7458
2	308-R	Normal	450.3333	4.9416
2	316-R	Phantoms	320.8333	2.0678
2	320-R	Normal	468.0000	3.3653
2	328-R	Doves	597.8333	2.0075
2	336-R	Normal	448.3333	4.3597
2	340-R	Normal	511.8333	3.2298
2	348-R	Normal	494.5000	4.7740
2	352-R	Doves	530.6667	2.7156
2	400-R	Normal	426.1667	2.8098
2	412-R	Normal	399.3333	4.0282
2	416-R	Normal	91.8333	3.6328
2	420-R	Normal	611.3333	3.4068

2	424-R	Phantoms	345.0000	2.9322
2	432-R	Normal	419.0000	4.3352
2	436-R	Normal	475.1667	4.0847
3	4-L	Normal	495.8333	3.5367
3	20-L	Normal	491.0000	6.6158
3	36-L	Normal	574.5000	4.5800
3	52-L	Normal	592.5000	4.1036
3	72-L	Normal	399.5000	4.1394
3	108-L	Normal	513.1667	7.3220
3	124-L	Phantoms	270.0000	2.5047
3	148-L	Normal	317.5000	3.6836
3	152-L	Phantoms	381.6667	1.5179
3	168-L	Normal	471.1667	2.8738
3	208-L	Normal	374.6667	3.3616
3	216-L	Normal	302.3333	4.8832
3	240-L	Normal	514.3333	4.2429
3	252-L	Normal	472.3333	4.8776
3	284-L	Normal	257.8333	3.3352
3	308-L	Normal	414.0000	3.7006
3	316-L	Normal	520.1667	5.8437
3	320-L	Normal	397.8333	3.2166
3	324-L	Normal	480.3333	5.9642
3	328-L	Normal	655.3333	3.7646
3	336-L	Normal	364.6667	3.3352
3	340-L	Chameleons	614.5000	5.9134
3	348-L	Chameleons	563.5000	5.0791
3	352-L	Normal	627.8333	3.5311
3	384-L	Phantoms	374.3333	2.2392
3	400-L	Normal	660.0000	4.0151
3	412-L	Normal	503.0000	2.6874
3	416-L	Normal	424.8333	5.1488
3	420-L	Normal	458.3333	3.0508
3	424-L	Phantoms	316.3333	2.7815
3	432-L	Normal	387.3333	3.8211
3	436-L	Normal	533.6667	4.5687
3	4-R	Normal	521.5000	2.8060
3	20-R	Normal	444.0000	4.0094
3	36-R	Chameleons	756.8333	7.2542
3	52-R	Normal	601.1667	4.7062
3	108-R	Chameleons	642.8333	6.3503
3	124-R	Phantoms	364.1667	2.9416

3	136-R	Normal	431.8333	3.1318
3	168-R	Normal	465.8333	4.0151
3	208-R	Phantoms	281.0000	2.6855
3	216-R	Normal	451.8333	6.2674
3	240-R	Normal	512.3333	4.1789
3	252-R	Normal	442.3333	4.1488
3	284-R	Chameleons	561.0000	5.0866
3	308-R	Phantoms	244.1667	2.6403
3	316-R	Normal	512.6667	3.3503
3	320-R	Normal	454.8333	2.1205
3	328-R	Chameleons	718.8333	4.8889
3	336-R	Normal	480.3333	4.1883
3	340-R	Normal	480.8333	3.9680
3	348-R	Normal	559.5000	4.1149
3	352-R	Normal	536.0000	2.9190
3	400-R	Phantoms	317.3333	2.8343
3	412-R	Normal	421.8333	2.7910
3	416-R	Chameleons	555.3333	5.4350
3	420-R	Normal	359.6667	3.6328
3	424-R	Phantoms	368.3333	2.7476
3	432-R	Normal	494.3333	5.1544
3	436-R	Normal	540.5000	4.5537
4	4-L	Normal	509.5000	2.8023
4	20-L	Worms	385.8333	6.2825
4	36-L	Normal	504.8333	3.6667
4	52-L	Normal	675.1667	3.4369
4	72-L	Normal	321.0000	4.7608
4	108-L	Chameleons	579.0000	6.6347
4	124-L	Normal	506.5000	2.5574
4	148-L	Normal	289.3333	3.2919
4	152-L	Normal	518.6667	1.3089
4	168-L	Normal	433.1667	2.9021
4	208-L	Normal	424.8333	3.5574
4	216-L	Normal	501.8333	6.2354
4	240-L	Normal	395.3333	4.6874
4	252-L	Normal	438.3333	5.2976
4	284-L	Normal	420.3333	3.3032
4	308-L	Normal	510.6667	5.2241
4	316-L	Chameleons	575.1667	6.1733
4	320-L	Normal	402.5000	3.4200
4	324-L	Worms	402.1667	5.6629

4	328-L	Normal	695.5000	4.5405
4	336-L	Normal	403.0000	5.1036
4	340-L	Normal	549.8333	5.9944
4	348-L	Normal	515.6667	5.3390
4	352-L	Normal	558.3333	3.1281
4	384-L	Normal	453.3333	2.8719
4	400-L	Normal	496.3333	3.4953
4	412-L	Normal	501.6667	3.2279
4	416-L	Normal	533.6667	4.5217
4	420-L	Normal	679.3333	3.2938
4	424-L	Phantoms	334.8333	1.3371
4	432-L	Normal	494.5000	4.2279
4	436-L	Normal	529.6667	4.6573
4	4-R	Normal	434.6667	2.4840
4	20-R	Normal	415.0000	4.3484
4	36-R	Chameleons	709.0000	6.7966
4	52-R	Chameleons	640.8333	5.2542
4	108-R	Chameleons	560.3333	7.0358
4	124-R	Phantoms	273.0000	2.7684
4	136-R	Phantoms	359.3333	2.4802
4	168-R	Normal	468.1667	4.2976
4	208-R	Phantoms	329.8333	2.6893
4	216-R	Chameleons	676.6667	6.0697
4	240-R	Normal	481.3333	4.3974
4	252-R	Normal	445.6667	3.7834
4	284-R	Normal	530.0000	6.1620
4	308-R	Normal	429.0000	4.6139
4	316-R	Normal	544.3333	3.0094
4	320-R	Phantoms	402.6667	2.6686
4	328-R	Normal	735.0000	4.4878
4	336-R	Normal	510.1667	4.8324
4	340-R	Doves	600.8333	2.9322
4	348-R	Normal	675.3333	5.0640
4	352-R	Normal	455.3333	3.4821
4	400-R	Normal	432.5000	3.2373
4	412-R	Normal	278.1667	3.2147
4	416-R	Normal	665.5000	3.7608
4	420-R	Normal	587.8333	3.6196
4	424-R	Phantoms	238.3333	2.1638
4	432-R	Normal	554.8333	4.9341
4	436-R	Normal	476.0000	4.7269

5	4-L	Normal	560.1667	3.1864
5	20-L	Normal	533.8333	7.3748
5	36-L	Normal	537.8333	4.3239
5	52-L	Normal	768.0000	4.0546
5	72-L	Normal	456.6667	3.7006
5	108-L	Chameleons	594.5000	6.5518
5	124-L	Phantoms	305.3333	2.3371
5	148-L	Normal	431.5000	4.1977
5	152-L	Normal	569.0000	1.3672
5	168-L	Phantoms	414.6667	2.9718
5	208-L	Phantoms	310.3333	2.0603
5	216-L	Normal	511.6667	4.7797
5	240-L	Normal	390.8333	3.4727
5	252-L	Chameleons	616.5000	5.9548
5	284-L	Normal	597.1667	4.3239
5	308-L	Normal	440.8333	4.2109
5	316-L	Normal	592.6667	5.1130
5	320-L	Normal	528.1667	3.6629
5	324-L	Normal	509.6667	5.3126
5	328-L	Normal	617.1667	3.7552
5	336-L	Normal	452.0000	2.7797
5	340-L	Normal	426.0000	5.4388
5	348-L	Normal	440.3333	3.9040
5	352-L	Normal	582.0000	3.1168
5	384-L	Phantoms	351.6667	2.9360
5	400-L	Normal	375.6667	3.1224
5	412-L	Normal	509.8333	1.6893
5	416-L	Normal	577.5000	5.1638
5	420-L	Normal	645.0000	3.4896
5	424-L	Phantoms	326.0000	2.3842
5	432-L	Worms	398.3333	4.5179
5	436-L	Normal	406.0000	3.1431
5	4-R	Phantoms	417.0000	2.0640
5	20-R	Normal	615.6667	4.2354
5	36-R	Chameleons	620.8333	5.9567
5	52-R	Chameleons	733.1667	4.5932
5	108-R	Chameleons	648.0000	6.7646
5	124-R	Normal	369.0000	3.0075
5	136-R	Normal	478.8333	2.9209
5	168-R	Normal	408.3333	3.2618
5	208-R	Phantoms	225.5000	1.6855

5	216-R	Chameleons	613.3333	6.4708
5	240-R	Normal	448.6667	4.0565
5	252-R	Normal	564.0000	4.0716
5	284-R	Chameleons	642.3333	5.4595
5	308-R	Normal	528.6667	3.9077
5	316-R	Normal	517.6667	2.7684
5	320-R	Normal	425.6667	3.2542
5	328-R	Doves	621.1667	2.0772
5	336-R	Normal	515.3333	3.4444
5	340-R	Normal	499.0000	2.4878
5	348-R	Normal	432.1667	3.6008
5	352-R	Normal	474.1667	3.0056
5	400-R	Phantoms	393.3333	2.9586
5	412-R	Normal	417.1667	3.3729
5	416-R	Normal	570.5000	3.9680
5	420-R	Normal	581.1667	3.5669
5	424-R	Normal	335.5000	2.9849
5	432-R	Normal	644.5000	4.2938
5	436-R	Normal	421.3333	3.5198
6	4-L	Normal	529.6667	3.8908
6	20-L	Normal	438.0000	8.2881
6	36-L	Normal	428.0000	4.4746
6	52-L	Normal	607.1667	4.0904
6	72-L	Normal	354.6667	4.4294
6	108-L	Normal	524.3333	7.0226
6	124-L	Phantoms	342.3333	2.5913
6	148-L	Normal	350.6667	3.7401
6	152-L	Normal	565.1667	1.3785
6	168-L	Phantoms	394.0000	2.3032
6	208-L	Normal	479.1667	3.5612
6	216-L	Normal	482.8333	5.1224
6	240-L	Normal	475.0000	4.5066
6	252-L	Normal	573.8333	5.5499
6	284-L	Normal	607.8333	4.2561
6	308-L	Normal	368.3333	4.5367
6	316-L	Normal	551.6667	6.3446
6	320-L	Normal	452.1667	3.9303
6	324-L	Normal	402.1667	5.1055
6	328-L	Normal	690.3333	4.0245
6	336-L	Normal	405.5000	3.4124
6	340-L	Normal	439.3333	4.7269

6	348-L	Normal	603.3333	4.8004
6	352-L	Phantoms	360.3333	2.8493
6	384-L	Phantoms	377.5000	2.3974
6	400-L	Normal	391.6667	3.3936
6	412-L	Normal	555.1667	2.7834
6	416-L	Normal	543.3333	5.8701
6	420-L	Normal	648.3333	3.5160
6	424-L	Normal	346.3333	3.3032
6	432-L	Phantoms	262.5000	2.6930
6	436-L	Normal	412.5000	4.3710
6	4-R	Normal	546.0000	3.4388
6	20-R	Normal	649.6667	4.4313
6	36-R	Chameleons	609.0000	6.8286
6	52-R	Chameleons	625.0000	5.7721
6	108-R	Chameleons	630.0000	7.3522
6	124-R	Normal	429.1667	3.1883
6	136-R	Normal	429.8333	2.3672
6	168-R	Normal	500.3333	3.7514
6	208-R	Phantoms	361.8333	2.5819
6	216-R	Chameleons	656.6667	6.8230
6	240-R	Normal	461.6667	3.6535
6	252-R	Normal	558.0000	4.4859
6	284-R	Chameleons	630.5000	5.6478
6	308-R	Normal	514.0000	4.4934
6	316-R	Phantoms	278.0000	3.2411
6	320-R	Normal	454.0000	3.1036
6	328-R	Normal	728.1667	3.3446
6	336-R	Chameleons	653.5000	5.8305
6	340-R	Normal	556.5000	3.2448
6	348-R	Normal	516.1667	4.2467
6	352-R	Normal	421.8333	2.4068
6	400-R	Phantoms	308.6667	3.2298
6	412-R	Normal	548.1667	3.9228
6	416-R	Normal	565.5000	5.1262
6	420-R	Normal	665.8333	4.4049
6	424-R	Normal	342.5000	3.5009
6	432-R	Normal	460.5000	5.1450
6	436-R	Normal	440.8333	3.7307

Appendix C: Stability Score Index by Subject Iris by Grouping

Table C1 *Stability Score Index of Subject Iris by Grouping*

SID	SSI	Grouping
4-L	0.119678	1-2
20-L	0.1647684	1-2
36-L	0.269095	1-2
52-L	0.0432645	1-2
72-L	0.1274544	1-2
108-L	0.0249452	1-2
124-L	0.0885542	1-2
136-L	0.0107569	1-2
152-L	0.1363798	1-2
168-L	0.1150989	1-2
208-L	0.1974742	1-2
216-L	0.2036566	1-2
240-L	0.0158843	1-2
252-L	0.0030238	1-2
284-L	0.0608666	1-2
308-L	0.0803378	1-2
316-L	0.0551819	1-2
320-L	0.0537784	1-2
324-L	0.4024977	1-2
328-L	0.0530942	1-2
336-L	0.1457597	1-2
340-L	0.0160259	1-2
348-L	0.2446115	1-2
352-L	0.0137299	1-2
384-L	0.0050404	1-2
400-L	0.2416358	1-2
412-L	0.0196804	1-2
416-L	0.0375679	1-2
420-L	0.0899279	1-2
424-L	0.0368412	1-2
432-L	0.042798	1-2
436-L	0.0491969	1-2
4-R	0.0153319	1-2
20-R	0.08947	1-2

36-R	0.148963	1-2
52-R	0.108702	1-2
108-R	0.1084619	1-2
124-R	0.1084616	1-2
136-R	0.5613056	1-2
168-R	0.010081	1-2
208-R	0.1357046	1-2
216-R	0.1192197	1-2
240-R	0.0887845	1-2
252-R	0.1070911	1-2
284-R	0.0517143	1-2
308-R	0.1057157	1-2
316-R	0.1233576	1-2
320-R	0.039815	1-2
328-R	0.1398281	1-2
336-R	0.0028084	1-2
340-R	0.0224287	1-2
348-R	0.1663534	1-2
352-R	0.0123858	1-2
400-R	0.1244815	1-2
412-R	0.1086906	1-2
416-R	0.0606509	1-2
420-R	0.0684198	1-2
424-R	0.1082346	1-2
432-R	0.1128145	1-2
436-R	0.0489749	1-2
4-L	0.059496	1-3
20-L	0.0775968	1-3
36-L	0.0645453	1-3
52-L	0.3354529	1-3
72-L	0.0219741	1-3
108-L	0.0074187	1-3
124-L	0.18077	1-3
136-L	0.1848893	1-3
152-L	0.1290567	1-3
168-L	0.1498785	1-3
208-L	0.109611	1-3
216-L	0.5006619	1-3
240-L	0.0216239	1-3

252-L	0.0021136	1-3
284-L	0.2928925	1-3
308-L	0.0176261	1-3
316-L	0.1535517	1-3
320-L	0.0119713	1-3
324-L	0.0501457	1-3
328-L	0.0851252	1-3
336-L	0.0368442	1-3
340-L	0.2045714	1-3
348-L	0.0375352	1-3
352-L	0.0017168	1-3
384-L	0.0961061	1-3
400-L	0.092445	1-3
412-L	0.0810032	1-3
416-L	0.4885366	1-3
420-L	0.3288169	1-3
424-L	0.0425719	1-3
432-L	0.0446239	1-3
436-L	0.1640705	1-3
4-R	0.0629262	1-3
20-R	0.137756	1-3
36-R	0.0180917	1-3
52-R	0.1709301	1-3
108-R	0.0906152	1-3
124-R	0.0958764	1-3
136-R	0.4443808	1-3
168-R	0.0558329	1-3
208-R	0.0411915	1-3
216-R	0.4054721	1-3
240-R	0.2015924	1-3
252-R	0.1535539	1-3
284-R	0.2066292	1-3
308-R	0.1773677	1-3
316-R	0.1400403	1-3
320-R	0.0218097	1-3
328-R	0.0263704	1-3
336-R	0.0466869	1-3
340-R	0.0201879	1-3
348-R	0.0771182	1-3

352-R	0.019687	1-3
400-R	0.2739006	1-3
412-R	0.0778234	1-3
416-R	0.5757167	1-3
420-R	0.2771044	1-3
424-R	0.1402706	1-3
432-R	0.0093817	1-3
436-R	0.1386738	1-3
4-L	0.0407331	1-4
20-L	0.2219709	1-4
36-L	0.1601754	1-4
52-L	0.4489501	1-4
72-L	0.0858198	1-4
108-L	0.0972672	1-4
124-L	0.1439297	1-4
136-L	0.2235589	1-4
152-L	0.0590421	1-4
168-L	0.0977074	1-4
208-L	0.1784861	1-4
216-L	0.2267691	1-4
240-L	0.1418786	1-4
252-L	0.0446204	1-4
284-L	0.0697942	1-4
308-L	0.1153288	1-4
316-L	0.2290631	1-4
320-L	0.0183351	1-4
324-L	0.0572232	1-4
328-L	0.029977	1-4
336-L	0.0895185	1-4
340-L	0.1157935	1-4
348-L	0.0281688	1-4
352-L	0.0970205	1-4
384-L	0.2045671	1-4
400-L	0.1322593	1-4
412-L	0.0791783	1-4
416-L	0.6379553	1-4
420-L	0.0253992	1-4
424-L	0.0171914	1-4
432-L	0.1025184	1-4

436-L	0.15858	1-4
4-R	0.0562908	1-4
20-R	0.1775672	1-4
36-R	0.0837488	1-4
52-R	0.2253899	1-4
108-R	0.0227041	1-4
124-R	0.2210421	1-4
136-R	0.3448398	1-4
168-R	0.0590388	1-4
208-R	0.1082341	1-4
216-R	0.0967917	1-4
240-R	0.1590329	1-4
252-R	0.158124	1-4
284-R	0.2491871	1-4
308-R	0.0764288	1-4
316-R	0.1835182	1-4
320-R	0.0498934	1-4
328-R	0.0485242	1-4
336-R	0.0876387	1-4
340-R	0.1446153	1-4
348-R	0.0819191	1-4
352-R	0.0910713	1-4
400-R	0.115784	1-4
412-R	0.2750471	1-4
416-R	0.7269674	1-4
420-R	0.0361635	1-4
424-R	0.0382507	1-4
432-R	0.0736811	1-4
436-R	0.0501412	1-4
4-L	0.0288316	1-5
20-L	0.0187888	1-5
36-L	0.1148743	1-5
52-L	0.5764021	1-5
72-L	0.1004527	1-5
108-L	0.1185427	1-5
124-L	0.1322612	1-5
136-L	0.0284087	1-5
152-L	0.1281425	1-5
168-L	0.0723088	1-5

208-L	0.0212919	1-5
216-L	0.213262	1-5
240-L	0.148084	1-5
252-L	0.1999927	1-5
284-L	0.1729907	1-5
308-L	0.0195708	1-5
316-L	0.2530786	1-5
320-L	0.1908387	1-5
324-L	0.0903895	1-5
328-L	0.1375241	1-5
336-L	0.156743	1-5
340-L	0.0542358	1-5
348-L	0.131575	1-5
352-L	0.0645277	1-5
384-L	0.0649874	1-5
400-L	0.297927	1-5
412-L	0.0903918	1-5
416-L	0.6981367	1-5
420-L	0.072537	1-5
424-L	0.0292923	1-5
432-L	0.0295577	1-5
436-L	0.0112304	1-5
4-R	0.0805496	1-5
20-R	0.09794	1-5
36-R	0.2047982	1-5
52-R	0.352157	1-5
108-R	0.0977136	1-5
124-R	0.0892405	1-5
136-R	0.5089059	1-5
168-R	0.0231263	1-5
208-R	0.0350196	1-5
216-R	0.1837444	1-5
240-R	0.1141824	1-5
252-R	0.3205855	1-5
284-R	0.0949632	1-5
308-R	0.2132676	1-5
316-R	0.1469103	1-5
320-R	0.018307	1-5
328-R	0.1077963	1-5

336-R	0.0947501	1-5
340-R	0.0048413	1-5
348-R	0.2519379	1-5
352-R	0.0652158	1-5
400-R	0.1695579	1-5
412-R	0.0842141	1-5
416-R	0.5965388	1-5
420-R	0.0270118	1-5
424-R	0.0951915	1-5
432-R	0.1967901	1-5
436-R	0.0249416	1-5
4-L	0.0130824	1-6
20-L	0.1503361	1-6
36-L	0.2656655	1-6
52-L	0.3555892	1-6
72-L	0.0395979	1-6
108-L	0.0223253	1-6
124-L	0.0814616	1-6
136-L	0.1393546	1-6
152-L	0.1228796	1-6
168-L	0.0439367	1-6
208-L	0.2530805	1-6
216-L	0.2528481	1-6
240-L	0.032546	1-6
252-L	0.1414125	1-6
284-L	0.1876348	1-6
308-L	0.0801061	1-6
316-L	0.1968043	1-6
320-L	0.0864953	1-6
324-L	0.0572093	1-6
328-L	0.0370715	1-6
336-L	0.0929039	1-6
340-L	0.0359258	1-6
348-L	0.092216	1-6
352-L	0.3688607	1-6
384-L	0.100453	1-6
400-L	0.2759594	1-6
412-L	0.1526246	1-6
416-L	0.6512313	1-6

420-L	0.0679608	1-6
424-L	0.0021761	1-6
432-L	0.2160099	1-6
436-L	0.0025164	1-6
4-R	0.0965685	1-6
20-R	0.1446168	1-6
36-R	0.2210418	1-6
52-R	0.2036547	1-6
108-R	0.0730203	1-6
124-R	0.0066387	1-6
136-R	0.4416295	1-6
168-R	0.1031988	1-6
208-R	0.152167	1-6
216-R	0.1242535	1-6
240-R	0.1320304	1-6
252-R	0.3123523	1-6
284-R	0.111208	1-6
308-R	0.193127	1-6
316-R	0.1821437	1-6
320-R	0.0205982	1-6
328-R	0.0391306	1-6
336-R	0.284429	1-6
340-R	0.08375	1-6
348-R	0.1366085	1-6
352-R	0.1370702	1-6
400-R	0.2857984	1-6
412-R	0.0956483	1-6
416-R	0.5896741	1-6
420-R	0.1432552	1-6
424-R	0.1048005	1-6
432-R	0.0558325	1-6
436-R	0.0018626	1-6
4-L	0.119678	2-1
20-L	0.1647684	2-1
36-L	0.269095	2-1
52-L	0.0432645	2-1
72-L	0.1274544	2-1
108-L	0.0249452	2-1
124-L	0.0885542	2-1

136-L	0.0107569	2-1
152-L	0.1363798	2-1
168-L	0.1150989	2-1
208-L	0.1974742	2-1
216-L	0.2036566	2-1
240-L	0.0158843	2-1
252-L	0.0030238	2-1
284-L	0.0608666	2-1
308-L	0.0803378	2-1
316-L	0.0551819	2-1
320-L	0.0537784	2-1
324-L	0.4024977	2-1
328-L	0.0530942	2-1
336-L	0.1457597	2-1
340-L	0.0160259	2-1
348-L	0.2446115	2-1
352-L	0.0137299	2-1
384-L	0.0050404	2-1
400-L	0.2416358	2-1
412-L	0.0196804	2-1
416-L	0.0375679	2-1
420-L	0.0899279	2-1
424-L	0.0368412	2-1
432-L	0.042798	2-1
436-L	0.0491969	2-1
4-R	0.0153319	2-1
20-R	0.08947	2-1
36-R	0.148963	2-1
52-R	0.108702	2-1
108-R	0.1084619	2-1
124-R	0.1084616	2-1
136-R	0.5613056	2-1
168-R	0.010081	2-1
208-R	0.1357046	2-1
216-R	0.1192197	2-1
240-R	0.0887845	2-1
252-R	0.1070911	2-1
284-R	0.0517143	2-1
308-R	0.1057157	2-1

316-R	0.1233576	2-1
320-R	0.039815	2-1
328-R	0.1398281	2-1
336-R	0.0028084	2-1
340-R	0.0224287	2-1
348-R	0.1663534	2-1
352-R	0.0123858	2-1
400-R	0.1244815	2-1
412-R	0.1086906	2-1
416-R	0.0606509	2-1
420-R	0.0684198	2-1
424-R	0.1082346	2-1
432-R	0.1128145	2-1
436-R	0.0489749	2-1
4-L	0.0601996	2-3
20-L	0.0871817	2-3
36-L	0.2045688	2-3
52-L	0.2922096	2-3
72-L	0.1494238	2-3
108-L	0.0318957	2-3
124-L	0.0922159	2-3
136-L	0.174134	2-3
152-L	0.007325	2-3
168-L	0.0347825	2-3
208-L	0.0878686	2-3
216-L	0.2970148	2-3
240-L	0.0373011	2-3
252-L	0.0009177	2-3
284-L	0.3537589	2-3
308-L	0.0629342	2-3
316-L	0.0983934	2-3
320-L	0.0656742	2-3
324-L	0.3523929	2-3
328-L	0.1382185	2-3
336-L	0.1089195	2-3
340-L	0.1885511	2-3
348-L	0.2821413	2-3
352-L	0.0121373	2-3
384-L	0.0910737	2-3

400-L	0.3340801	2-3
412-L	0.1006828	2-3
416-L	0.5260612	2-3
420-L	0.2388909	2-3
424-L	0.005852	2-3
432-L	0.0874103	2-3
436-L	0.1148745	2-3
4-R	0.0782578	2-3
20-R	0.0482891	2-3
36-R	0.130889	2-3
52-R	0.0622532	2-3
108-R	0.199075	2-3
124-R	0.0125852	2-3
136-R	0.1169281	2-3
168-R	0.0457697	2-3
208-R	0.0945131	2-3
216-R	0.2862579	2-3
240-R	0.1128136	2-3
252-R	0.0464711	2-3
284-R	0.1549149	2-3
308-R	0.2830701	2-3
316-R	0.2633797	2-3
320-R	0.0181575	2-3
328-R	0.1661717	2-3
336-R	0.0439344	2-3
340-R	0.0425729	2-3
348-R	0.0892451	2-3
352-R	0.0073276	2-3
400-R	0.1494206	2-3
412-R	0.0309376	2-3
416-R	0.636358	2-3
420-R	0.3455209	2-3
424-R	0.0320361	2-3
432-R	0.1034335	2-3
436-R	0.0897004	2-3
4-L	0.0789452	2-4
20-L	0.0572056	2-4
36-L	0.1089196	2-4
52-L	0.4057086	2-4

72-L	0.0416859	2-4
108-L	0.1221993	2-4
124-L	0.2324831	2-4
136-L	0.2128042	2-4
152-L	0.1954138	2-4
168-L	0.017393	2-4
208-L	0.019005	2-4
216-L	0.0231126	2-4
240-L	0.1260808	2-4
252-L	0.0475993	2-4
284-L	0.1306587	2-4
308-L	0.1956455	2-4
316-L	0.173905	2-4
320-L	0.0720794	2-4
324-L	0.4597067	2-4
328-L	0.0830645	2-4
336-L	0.0563543	2-4
340-L	0.0997711	2-4
348-L	0.2164736	2-4
352-L	0.0832912	2-4
384-L	0.1995326	2-4
400-L	0.1093771	2-4
412-L	0.0988587	2-4
416-L	0.6754827	2-4
420-L	0.0645289	2-4
424-L	0.019693	2-4
432-L	0.0597232	2-4
436-L	0.1093844	2-4
4-R	0.0409592	2-4
20-R	0.0880973	2-4
36-R	0.0652147	2-4
52-R	0.1167172	2-4
108-R	0.0858167	2-4
124-R	0.1125806	2-4
136-R	0.2164663	2-4
168-R	0.0489799	2-4
208-R	0.0274918	2-4
216-R	0.0224384	2-4
240-R	0.0702605	2-4

252-R	0.0510347	2-4
284-R	0.1974739	2-4
308-R	0.0292926	2-4
316-R	0.3068526	2-4
320-R	0.0897032	2-4
328-R	0.1883511	2-4
336-R	0.0848953	2-4
340-R	0.1221914	2-4
348-R	0.2482719	2-4
352-R	0.1034328	2-4
400-R	0.008715	2-4
412-R	0.1663572	2-4
416-R	0.7876044	2-4
420-R	0.0322652	2-4
424-R	0.1464497	2-4
432-R	0.1864915	2-4
436-R	0.0014444	2-4
4-L	0.148509	2-5
20-L	0.1459947	2-5
36-L	0.1542269	2-5
52-L	0.5331572	2-5
72-L	0.2279068	2-5
108-L	0.1434774	2-5
124-L	0.043709	2-5
136-L	0.0176589	2-5
152-L	0.2645179	2-5
168-L	0.0427902	2-5
208-L	0.1761979	2-5
216-L	0.0097641	2-5
240-L	0.1322679	2-5
252-L	0.1970216	2-5
284-L	0.1121253	2-5
308-L	0.0997668	2-5
316-L	0.1979336	2-5
320-L	0.2446105	2-5
324-L	0.312116	2-5
328-L	0.1906159	2-5
336-L	0.0109949	2-5
340-L	0.0702486	2-5

348-L	0.113038	2-5
352-L	0.0507985	2-5
384-L	0.0599519	2-5
400-L	0.0562952	2-5
412-L	0.1100668	2-5
416-L	0.7356619	2-5
420-L	0.0173909	2-5
424-L	0.0075824	2-5
432-L	0.0723109	2-5
436-L	0.0604141	2-5
4-R	0.0652177	2-5
20-R	0.1874059	2-5
36-R	0.0558396	2-5
52-R	0.2434691	2-5
108-R	0.2061701	2-5
124-R	0.0192212	2-5
136-R	0.0524002	2-5
168-R	0.0331808	2-5
208-R	0.1707228	2-5
216-R	0.0645416	2-5
240-R	0.0254131	2-5
252-R	0.2134944	2-5
284-R	0.0432491	2-5
308-R	0.1075556	2-5
316-R	0.2702402	2-5
320-R	0.0581209	2-5
328-R	0.0320352	2-5
336-R	0.0919949	2-5
340-R	0.0176487	2-5
348-R	0.0855945	2-5
352-R	0.0775716	2-5
400-R	0.0450783	2-5
412-R	0.0245004	2-5
416-R	0.6571762	2-5
420-R	0.0414173	2-5
424-R	0.013043	2-5
432-R	0.3095958	2-5
436-R	0.0739135	2-5
4-L	0.10665	2-6

20-L	0.0146532	2-6
36-L	0.0035223	2-6
52-L	0.3123458	2-6
72-L	0.0878783	2-6
108-L	0.0471786	2-6
124-L	0.0070978	2-6
136-L	0.128599	2-6
152-L	0.259255	2-6
168-L	0.0711723	2-6
208-L	0.0556081	2-6
216-L	0.0492127	2-6
240-L	0.0167044	2-6
252-L	0.1384407	2-6
284-L	0.126769	2-6
308-L	0.0002628	2-6
316-L	0.1416421	2-6
320-L	0.1402683	2-6
324-L	0.4597042	2-6
328-L	0.0901654	2-6
336-L	0.0528591	2-6
340-L	0.051948	2-6
348-L	0.3368275	2-6
352-L	0.3551316	2-6
384-L	0.0954198	2-6
400-L	0.0343254	2-6
412-L	0.1723039	2-6
416-L	0.6887537	2-6
420-L	0.0219671	2-6
424-L	0.0355209	2-6
432-L	0.2588038	2-6
436-L	0.0514927	2-6
4-R	0.1119004	2-6
20-R	0.2340848	2-6
36-R	0.0720795	2-6
52-R	0.0950013	2-6
108-R	0.1814631	2-6
124-R	0.1018262	2-6
136-R	0.1196765	2-6
168-R	0.0931311	2-6

208-R	0.016543	2-6
216-R	0.005353	2-6
240-R	0.0432483	2-6
252-R	0.2052613	2-6
284-R	0.0594938	2-6
308-R	0.0874121	2-6
316-R	0.0588293	2-6
320-R	0.0192244	2-6
328-R	0.1789481	2-6
336-R	0.2816868	2-6
340-R	0.0613242	2-6
348-R	0.0297557	2-6
352-R	0.1494212	2-6
400-R	0.1613203	2-6
412-R	0.2043379	2-6
416-R	0.6503146	2-6
420-R	0.0748373	2-6
424-R	0.00352	2-6
432-R	0.0569875	2-6
436-R	0.0471398	2-6
4-L	0.059496	3-1
20-L	0.0775968	3-1
36-L	0.0645453	3-1
52-L	0.3354529	3-1
72-L	0.0219741	3-1
108-L	0.0074187	3-1
124-L	0.18077	3-1
136-L	0.1848893	3-1
152-L	0.1290567	3-1
168-L	0.1498785	3-1
208-L	0.109611	3-1
216-L	0.5006619	3-1
240-L	0.0216239	3-1
252-L	0.0021136	3-1
284-L	0.2928925	3-1
308-L	0.0176261	3-1
316-L	0.1535517	3-1
320-L	0.0119713	3-1
324-L	0.0501457	3-1

328-L	0.0851252	3-1
336-L	0.0368442	3-1
340-L	0.2045714	3-1
348-L	0.0375352	3-1
352-L	0.0017168	3-1
384-L	0.0961061	3-1
400-L	0.092445	3-1
412-L	0.0810032	3-1
416-L	0.4885366	3-1
420-L	0.3288169	3-1
424-L	0.0425719	3-1
432-L	0.0446239	3-1
436-L	0.1640705	3-1
4-R	0.0629262	3-1
20-R	0.137756	3-1
36-R	0.0180917	3-1
52-R	0.1709301	3-1
108-R	0.0906152	3-1
124-R	0.0958764	3-1
136-R	0.4443808	3-1
168-R	0.0558329	3-1
208-R	0.0411915	3-1
216-R	0.4054721	3-1
240-R	0.2015924	3-1
252-R	0.1535539	3-1
284-R	0.2066292	3-1
308-R	0.1773677	3-1
316-R	0.1400403	3-1
320-R	0.0218097	3-1
328-R	0.0263704	3-1
336-R	0.0466869	3-1
340-R	0.0201879	3-1
348-R	0.0771182	3-1
352-R	0.019687	3-1
400-R	0.2739006	3-1
412-R	0.0778234	3-1
416-R	0.5757167	3-1
420-R	0.2771044	3-1
424-R	0.1402706	3-1

432-R	0.0093817	3-1
436-R	0.1386738	3-1
4-L	0.0601996	3-2
20-L	0.0871817	3-2
36-L	0.2045688	3-2
52-L	0.2922096	3-2
72-L	0.1494238	3-2
108-L	0.0318957	3-2
124-L	0.0922159	3-2
136-L	0.174134	3-2
152-L	0.007325	3-2
168-L	0.0347825	3-2
208-L	0.0878686	3-2
216-L	0.2970148	3-2
240-L	0.0373011	3-2
252-L	0.0009177	3-2
284-L	0.3537589	3-2
308-L	0.0629342	3-2
316-L	0.0983934	3-2
320-L	0.0656742	3-2
324-L	0.3523929	3-2
328-L	0.1382185	3-2
336-L	0.1089195	3-2
340-L	0.1885511	3-2
348-L	0.2821413	3-2
352-L	0.0121373	3-2
384-L	0.0910737	3-2
400-L	0.3340801	3-2
412-L	0.1006828	3-2
416-L	0.5260612	3-2
420-L	0.2388909	3-2
424-L	0.005852	3-2
432-L	0.0874103	3-2
436-L	0.1148745	3-2
4-R	0.0782578	3-2
20-R	0.0482891	3-2
36-R	0.130889	3-2
52-R	0.0622532	3-2
108-R	0.199075	3-2

124-R	0.0125852	3-2
136-R	0.1169281	3-2
168-R	0.0457697	3-2
208-R	0.0945131	3-2
216-R	0.2862579	3-2
240-R	0.1128136	3-2
252-R	0.0464711	3-2
284-R	0.1549149	3-2
308-R	0.2830701	3-2
316-R	0.2633797	3-2
320-R	0.0181575	3-2
328-R	0.1661717	3-2
336-R	0.0439344	3-2
340-R	0.0425729	3-2
348-R	0.0892451	3-2
352-R	0.0073276	3-2
400-R	0.1494206	3-2
412-R	0.0309376	3-2
416-R	0.636358	3-2
420-R	0.3455209	3-2
424-R	0.0320361	3-2
432-R	0.1034335	3-2
436-R	0.0897004	3-2
4-L	0.0187904	3-4
20-L	0.1443872	3-4
36-L	0.0956557	3-4
52-L	0.1134993	3-4
72-L	0.1077784	3-4
108-L	0.0903895	3-4
124-L	0.324698	3-4
136-L	0.0386746	3-4
152-L	0.1880917	3-4
168-L	0.0521714	3-4
208-L	0.0688759	3-4
216-L	0.2739059	3-4
240-L	0.1633798	3-4
252-L	0.0466832	3-4
284-L	0.2231012	3-4
308-L	0.1327331	3-4

316-L	0.0755125	3-4
320-L	0.0064131	3-4
324-L	0.1073182	3-4
328-L	0.0551564	3-4
336-L	0.052685	3-4
340-L	0.0887829	3-4
348-L	0.0656728	3-4
352-L	0.0954203	3-4
384-L	0.108465	3-4
400-L	0.2247041	3-4
412-L	0.0019753	3-4
416-L	0.1494231	3-4
420-L	0.3034178	3-4
424-L	0.0254765	3-4
432-L	0.1471334	3-4
436-L	0.0054931	3-4
4-R	0.119217	3-4
20-R	0.0398177	3-4
36-R	0.0656748	3-4
52-R	0.0544647	3-4
108-R	0.1132707	3-4
124-R	0.1251657	3-4
136-R	0.0995415	3-4
168-R	0.0032269	3-4
208-R	0.0670448	3-4
216-R	0.3086806	3-4
240-R	0.0425619	3-4
252-R	0.0046038	3-4
284-R	0.0425864	3-4
308-R	0.2537778	3-4
316-R	0.0434786	3-4
320-R	0.0716252	3-4
328-R	0.0222026	3-4
336-R	0.0409686	3-4
340-R	0.1647577	3-4
348-R	0.1590364	3-4
352-R	0.1107524	3-4
400-R	0.1581168	3-4
412-R	0.1972452	3-4

416-R	0.1512687	3-4
420-R	0.3132569	3-4
424-R	0.1784828	3-4
432-R	0.0830628	3-4
436-R	0.0885543	3-4
4-L	0.0883265	3-5
20-L	0.0588164	3-5
36-L	0.050342	3-5
52-L	0.2409493	3-5
72-L	0.0784882	3-5
108-L	0.11167	3-5
124-L	0.0485108	3-5
136-L	0.1565157	3-5
152-L	0.2571957	3-5
168-L	0.0775707	3-5
208-L	0.0883432	3-5
216-L	0.2874001	3-5
240-L	0.1695602	3-5
252-L	0.1979363	3-5
284-L	0.465883	3-5
308-L	0.036847	3-5
316-L	0.0995425	3-5
320-L	0.1789397	3-5
324-L	0.0402825	3-5
328-L	0.0524001	3-5
336-L	0.119905	3-5
340-L	0.2587982	3-5
348-L	0.1691069	3-5
352-L	0.0629285	3-5
384-L	0.0311345	3-5
400-L	0.3903718	3-5
412-L	0.0094813	3-5
416-L	0.2096007	3-5
420-L	0.256281	3-5
424-L	0.0132829	3-5
432-L	0.0151325	3-5
436-L	0.1752884	3-5
4-R	0.1434748	3-5
20-R	0.2356866	3-5

36-R	0.186727	3-5
52-R	0.1812269	3-5
108-R	0.0071163	3-5
124-R	0.0066365	3-5
136-R	0.0645284	3-5
168-R	0.0789503	3-5
208-R	0.07621	3-5
216-R	0.2217284	3-5
240-R	0.08741	3-5
252-R	0.1670399	3-5
284-R	0.1116661	3-5
308-R	0.3906026	3-5
316-R	0.006911	3-5
320-R	0.0400741	3-5
328-R	0.134145	3-5
336-R	0.0480634	3-5
340-R	0.0250242	3-5
348-R	0.1748212	3-5
352-R	0.084893	3-5
400-R	0.1043428	3-5
412-R	0.0064567	3-5
416-R	0.02092	3-5
420-R	0.3041041	3-5
424-R	0.0450791	3-5
432-R	0.2061717	3-5
436-R	0.1636137	3-5
4-L	0.0464534	3-6
20-L	0.0728015	3-6
36-L	0.2011343	3-6
52-L	0.0201363	3-6
72-L	0.0615543	3-6
108-L	0.0153365	3-6
124-L	0.0993087	3-6
136-L	0.0455356	3-6
152-L	0.2519328	3-6
168-L	0.1059473	3-6
208-L	0.1434715	3-6
216-L	0.2478141	3-6
240-L	0.0540031	3-6

252-L	0.1393554	3-6
284-L	0.4805272	3-6
308-L	0.0627076	3-6
316-L	0.0432528	3-6
320-L	0.0746023	3-6
324-L	0.1073239	3-6
328-L	0.0480539	3-6
336-L	0.0560614	3-6
340-L	0.2404971	3-6
348-L	0.0546897	3-6
352-L	0.36726	3-6
384-L	0.004353	3-6
400-L	0.368404	3-6
412-L	0.0716213	3-6
416-L	0.1626952	3-6
420-L	0.2608575	3-6
424-L	0.0411941	3-6
432-L	0.1713945	3-6
436-L	0.1663536	3-6
4-R	0.033648	3-6
20-R	0.2823666	3-6
36-R	0.2029657	3-6
52-R	0.0327542	3-6
108-R	0.0176729	3-6
124-R	0.0892411	3-6
136-R	0.0029397	3-6
168-R	0.0473675	3-6
208-R	0.1109786	3-6
216-R	0.2812229	3-6
240-R	0.0695655	3-6
252-R	0.1588029	3-6
284-R	0.0954218	3-6
308-R	0.3704711	3-6
316-R	0.3221811	3-6
320-R	0.0017694	3-6
328-R	0.0129883	3-6
336-R	0.2377564	3-6
340-R	0.1038898	3-6
348-R	0.0594939	3-6

352-R	0.1567444	3-6
400-R	0.0119111	3-6
412-R	0.1734538	3-6
416-R	0.0139646	3-6
420-R	0.4203468	3-6
424-R	0.0354825	3-6
432-R	0.0464508	3-6
436-R	0.13684	3-6
4-L	0.0407331	4-1
20-L	0.2219709	4-1
36-L	0.1601754	4-1
52-L	0.4489501	4-1
72-L	0.0858198	4-1
108-L	0.0972672	4-1
124-L	0.1439297	4-1
136-L	0.2235589	4-1
152-L	0.0590421	4-1
168-L	0.0977074	4-1
208-L	0.1784861	4-1
216-L	0.2267691	4-1
240-L	0.1418786	4-1
252-L	0.0446204	4-1
284-L	0.0697942	4-1
308-L	0.1153288	4-1
316-L	0.2290631	4-1
320-L	0.0183351	4-1
324-L	0.0572232	4-1
328-L	0.029977	4-1
336-L	0.0895185	4-1
340-L	0.1157935	4-1
348-L	0.0281688	4-1
352-L	0.0970205	4-1
384-L	0.2045671	4-1
400-L	0.1322593	4-1
412-L	0.0791783	4-1
416-L	0.6379553	4-1
420-L	0.0253992	4-1
424-L	0.0171914	4-1
432-L	0.1025184	4-1

436-L	0.15858	4-1
4-R	0.0562908	4-1
20-R	0.1775672	4-1
36-R	0.0837488	4-1
52-R	0.2253899	4-1
108-R	0.0227041	4-1
124-R	0.2210421	4-1
136-R	0.3448398	4-1
168-R	0.0590388	4-1
208-R	0.1082341	4-1
216-R	0.0967917	4-1
240-R	0.1590329	4-1
252-R	0.158124	4-1
284-R	0.2491871	4-1
308-R	0.0764288	4-1
316-R	0.1835182	4-1
320-R	0.0498934	4-1
328-R	0.0485242	4-1
336-R	0.0876387	4-1
340-R	0.1446153	4-1
348-R	0.0819191	4-1
352-R	0.0910713	4-1
400-R	0.115784	4-1
412-R	0.2750471	4-1
416-R	0.7269674	4-1
420-R	0.0361635	4-1
424-R	0.0382507	4-1
432-R	0.0736811	4-1
436-R	0.0501412	4-1
4-L	0.0789452	4-2
20-L	0.0572056	4-2
36-L	0.1089196	4-2
52-L	0.4057086	4-2
72-L	0.0416859	4-2
108-L	0.1221993	4-2
124-L	0.2324831	4-2
136-L	0.2128042	4-2
152-L	0.1954138	4-2
168-L	0.017393	4-2

208-L	0.019005	4-2
216-L	0.0231126	4-2
240-L	0.1260808	4-2
252-L	0.0475993	4-2
284-L	0.1306587	4-2
308-L	0.1956455	4-2
316-L	0.173905	4-2
320-L	0.0720794	4-2
324-L	0.4597067	4-2
328-L	0.0830645	4-2
336-L	0.0563543	4-2
340-L	0.0997711	4-2
348-L	0.2164736	4-2
352-L	0.0832912	4-2
384-L	0.1995326	4-2
400-L	0.1093771	4-2
412-L	0.0988587	4-2
416-L	0.6754827	4-2
420-L	0.0645289	4-2
424-L	0.019693	4-2
432-L	0.0597232	4-2
436-L	0.1093844	4-2
4-R	0.0409592	4-2
20-R	0.0880973	4-2
36-R	0.0652147	4-2
52-R	0.1167172	4-2
108-R	0.0858167	4-2
124-R	0.1125806	4-2
136-R	0.2164663	4-2
168-R	0.0489799	4-2
208-R	0.0274918	4-2
216-R	0.0224384	4-2
240-R	0.0702605	4-2
252-R	0.0510347	4-2
284-R	0.1974739	4-2
308-R	0.0292926	4-2
316-R	0.3068526	4-2
320-R	0.0897032	4-2
328-R	0.1883511	4-2

336-R	0.0848953	4-2
340-R	0.1221914	4-2
348-R	0.2482719	4-2
352-R	0.1034328	4-2
400-R	0.008715	4-2
412-R	0.1663572	4-2
416-R	0.7876044	4-2
420-R	0.0322652	4-2
424-R	0.1464497	4-2
432-R	0.1864915	4-2
436-R	0.0014444	4-2
4-L	0.0187904	4-3
20-L	0.1443872	4-3
36-L	0.0956557	4-3
52-L	0.1134993	4-3
72-L	0.1077784	4-3
108-L	0.0903895	4-3
124-L	0.324698	4-3
136-L	0.0386746	4-3
152-L	0.1880917	4-3
168-L	0.0521714	4-3
208-L	0.0688759	4-3
216-L	0.2739059	4-3
240-L	0.1633798	4-3
252-L	0.0466832	4-3
284-L	0.2231012	4-3
308-L	0.1327331	4-3
316-L	0.0755125	4-3
320-L	0.0064131	4-3
324-L	0.1073182	4-3
328-L	0.0551564	4-3
336-L	0.052685	4-3
340-L	0.0887829	4-3
348-L	0.0656728	4-3
352-L	0.0954203	4-3
384-L	0.108465	4-3
400-L	0.2247041	4-3
412-L	0.0019753	4-3
416-L	0.1494231	4-3

420-L	0.3034178	4-3
424-L	0.0254765	4-3
432-L	0.1471334	4-3
436-L	0.0054931	4-3
4-R	0.119217	4-3
20-R	0.0398177	4-3
36-R	0.0656748	4-3
52-R	0.0544647	4-3
108-R	0.1132707	4-3
124-R	0.1251657	4-3
136-R	0.0995415	4-3
168-R	0.0032269	4-3
208-R	0.0670448	4-3
216-R	0.3086806	4-3
240-R	0.0425619	4-3
252-R	0.0046038	4-3
284-R	0.0425864	4-3
308-R	0.2537778	4-3
316-R	0.0434786	4-3
320-R	0.0716252	4-3
328-R	0.0222026	4-3
336-R	0.0409686	4-3
340-R	0.1647577	4-3
348-R	0.1590364	4-3
352-R	0.1107524	4-3
400-R	0.1581168	4-3
412-R	0.1972452	4-3
416-R	0.1512687	4-3
420-R	0.3132569	4-3
424-R	0.1784828	4-3
432-R	0.0830628	4-3
436-R	0.0885543	4-3
4-L	0.0695638	4-5
20-L	0.2031992	4-5
36-L	0.0453156	4-5
52-L	0.1274565	4-5
72-L	0.1862666	4-5
108-L	0.0212807	4-5
124-L	0.276188	4-5

136-L	0.1951889	4-5
152-L	0.0691042	4-5
168-L	0.0253994	4-5
208-L	0.157214	4-5
216-L	0.0136476	4-5
240-L	0.0063993	4-5
252-L	0.2446121	4-5
284-L	0.2427839	4-5
308-L	0.0958864	4-5
316-L	0.0240703	4-5
320-L	0.1725319	4-5
324-L	0.1475908	4-5
328-L	0.1075516	4-5
336-L	0.0673492	4-5
340-L	0.1700162	4-5
348-L	0.1034462	4-5
352-L	0.0324927	4-5
384-L	0.1395813	4-5
400-L	0.1656677	4-5
412-L	0.0114095	4-5
416-L	0.0601865	4-5
420-L	0.047138	4-5
424-L	0.0122125	4-5
432-L	0.1320307	4-5
436-L	0.1697985	4-5
4-R	0.0242619	4-5
20-R	0.2755014	4-5
36-R	0.1210522	4-5
52-R	0.1267705	4-5
108-R	0.1203608	4-5
124-R	0.1318017	4-5
136-R	0.1640663	4-5
168-R	0.0821593	4-5
208-R	0.143249	4-5
216-R	0.0869541	4-5
240-R	0.0448515	4-5
252-R	0.1624639	4-5
284-R	0.1542288	4-5
308-R	0.1368389	4-5

316-R	0.0366129	4-5
320-R	0.0315876	4-5
328-R	0.1563202	4-5
336-R	0.007345	4-5
340-R	0.1398114	4-5
348-R	0.3338569	4-5
352-R	0.0258651	4-5
400-R	0.0537745	4-5
412-R	0.1908374	4-5
416-R	0.1304287	4-5
420-R	0.0091531	4-5
424-R	0.1334078	4-5
432-R	0.1231093	4-5
436-R	0.0750718	4-5
4-L	0.0277278	4-6
20-L	0.0716741	4-6
36-L	0.1054927	4-6
52-L	0.0933636	4-6
72-L	0.0462242	4-6
108-L	0.0750554	4-6
124-L	0.2253894	4-6
136-L	0.0842086	4-6
152-L	0.0638413	4-6
168-L	0.0537794	4-6
208-L	0.0745959	4-6
216-L	0.0261304	4-6
240-L	0.1093771	4-6
252-L	0.1860323	4-6
284-L	0.2574277	4-6
308-L	0.195416	4-6
316-L	0.0322647	4-6
320-L	0.0681925	4-6
324-L	0.0007653	4-6
328-L	0.0071288	4-6
336-L	0.0041439	4-6
340-L	0.1517187	4-6
348-L	0.1203624	4-6
352-L	0.2718404	4-6
384-L	0.1041159	4-6

400-L	0.1437001	4-6
412-L	0.0734544	4-6
416-L	0.0134001	4-6
420-L	0.0425619	4-6
424-L	0.0160178	4-6
432-L	0.3185268	4-6
436-L	0.1608622	4-6
4-R	0.1528585	4-6
20-R	0.322181	4-6
36-R	0.137293	4-6
52-R	0.0217497	4-6
108-R	0.0956485	4-6
124-R	0.2144067	4-6
136-R	0.0967917	4-6
168-R	0.044169	4-6
208-R	0.043934	4-6
216-R	0.0274781	4-6
240-R	0.0270203	4-6
252-R	0.1542289	4-6
284-R	0.1379813	4-6
308-R	0.1166992	4-6
316-R	0.3656572	4-6
320-R	0.0704796	4-6
328-R	0.009512	4-6
336-R	0.1967915	4-6
340-R	0.0608681	4-6
348-R	0.2185276	4-6
352-R	0.0460169	4-6
400-R	0.1700146	4-6
412-R	0.3706925	4-6
416-R	0.1373058	4-6
420-R	0.107094	4-6
424-R	0.1430254	4-6
432-R	0.1295134	4-6
436-R	0.0483007	4-6
4-L	0.0288316	5-1
20-L	0.0187888	5-1
36-L	0.1148743	5-1
52-L	0.5764021	5-1

72-L	0.1004527	5-1
108-L	0.1185427	5-1
124-L	0.1322612	5-1
136-L	0.0284087	5-1
152-L	0.1281425	5-1
168-L	0.0723088	5-1
208-L	0.0212919	5-1
216-L	0.213262	5-1
240-L	0.148084	5-1
252-L	0.1999927	5-1
284-L	0.1729907	5-1
308-L	0.0195708	5-1
316-L	0.2530786	5-1
320-L	0.1908387	5-1
324-L	0.0903895	5-1
328-L	0.1375241	5-1
336-L	0.156743	5-1
340-L	0.0542358	5-1
348-L	0.131575	5-1
352-L	0.0645277	5-1
384-L	0.0649874	5-1
400-L	0.297927	5-1
412-L	0.0903918	5-1
416-L	0.6981367	5-1
420-L	0.072537	5-1
424-L	0.0292923	5-1
432-L	0.0295577	5-1
436-L	0.0112304	5-1
4-R	0.0805496	5-1
20-R	0.09794	5-1
36-R	0.2047982	5-1
52-R	0.352157	5-1
108-R	0.0977136	5-1
124-R	0.0892405	5-1
136-R	0.5089059	5-1
168-R	0.0231263	5-1
208-R	0.0350196	5-1
216-R	0.1837444	5-1
240-R	0.1141824	5-1

252-R	0.3205855	5-1
284-R	0.0949632	5-1
308-R	0.2132676	5-1
316-R	0.1469103	5-1
320-R	0.018307	5-1
328-R	0.1077963	5-1
336-R	0.0947501	5-1
340-R	0.0048413	5-1
348-R	0.2519379	5-1
352-R	0.0652158	5-1
400-R	0.1695579	5-1
412-R	0.0842141	5-1
416-R	0.5965388	5-1
420-R	0.0270118	5-1
424-R	0.0951915	5-1
432-R	0.1967901	5-1
436-R	0.0249416	5-1
4-L	0.148509	5-2
20-L	0.1459947	5-2
36-L	0.1542269	5-2
52-L	0.5331572	5-2
72-L	0.2279068	5-2
108-L	0.1434774	5-2
124-L	0.043709	5-2
136-L	0.0176589	5-2
152-L	0.2645179	5-2
168-L	0.0427902	5-2
208-L	0.1761979	5-2
216-L	0.0097641	5-2
240-L	0.1322679	5-2
252-L	0.1970216	5-2
284-L	0.1121253	5-2
308-L	0.0997668	5-2
316-L	0.1979336	5-2
320-L	0.2446105	5-2
324-L	0.312116	5-2
328-L	0.1906159	5-2
336-L	0.0109949	5-2
340-L	0.0702486	5-2

348-L	0.113038	5-2
352-L	0.0507985	5-2
384-L	0.0599519	5-2
400-L	0.0562952	5-2
412-L	0.1100668	5-2
416-L	0.7356619	5-2
420-L	0.0173909	5-2
424-L	0.0075824	5-2
432-L	0.0723109	5-2
436-L	0.0604141	5-2
4-R	0.0652177	5-2
20-R	0.1874059	5-2
36-R	0.0558396	5-2
52-R	0.2434691	5-2
108-R	0.2061701	5-2
124-R	0.0192212	5-2
136-R	0.0524002	5-2
168-R	0.0331808	5-2
208-R	0.1707228	5-2
216-R	0.0645416	5-2
240-R	0.0254131	5-2
252-R	0.2134944	5-2
284-R	0.0432491	5-2
308-R	0.1075556	5-2
316-R	0.2702402	5-2
320-R	0.0581209	5-2
328-R	0.0320352	5-2
336-R	0.0919949	5-2
340-R	0.0176487	5-2
348-R	0.0855945	5-2
352-R	0.0775716	5-2
400-R	0.0450783	5-2
412-R	0.0245004	5-2
416-R	0.6571762	5-2
420-R	0.0414173	5-2
424-R	0.013043	5-2
432-R	0.3095958	5-2
436-R	0.0739135	5-2
4-L	0.0883265	5-3

20-L	0.0588164	5-3
36-L	0.050342	5-3
52-L	0.2409493	5-3
72-L	0.0784882	5-3
108-L	0.11167	5-3
124-L	0.0485108	5-3
136-L	0.1565157	5-3
152-L	0.2571957	5-3
168-L	0.0775707	5-3
208-L	0.0883432	5-3
216-L	0.2874001	5-3
240-L	0.1695602	5-3
252-L	0.1979363	5-3
284-L	0.465883	5-3
308-L	0.036847	5-3
316-L	0.0995425	5-3
320-L	0.1789397	5-3
324-L	0.0402825	5-3
328-L	0.0524001	5-3
336-L	0.119905	5-3
340-L	0.2587982	5-3
348-L	0.1691069	5-3
352-L	0.0629285	5-3
384-L	0.0311345	5-3
400-L	0.3903718	5-3
412-L	0.0094813	5-3
416-L	0.2096007	5-3
420-L	0.256281	5-3
424-L	0.0132829	5-3
432-L	0.0151325	5-3
436-L	0.1752884	5-3
4-R	0.1434748	5-3
20-R	0.2356866	5-3
36-R	0.186727	5-3
52-R	0.1812269	5-3
108-R	0.0071163	5-3
124-R	0.0066365	5-3
136-R	0.0645284	5-3
168-R	0.0789503	5-3

208-R	0.07621	5-3
216-R	0.2217284	5-3
240-R	0.08741	5-3
252-R	0.1670399	5-3
284-R	0.1116661	5-3
308-R	0.3906026	5-3
316-R	0.006911	5-3
320-R	0.0400741	5-3
328-R	0.134145	5-3
336-R	0.0480634	5-3
340-R	0.0250242	5-3
348-R	0.1748212	5-3
352-R	0.084893	5-3
400-R	0.1043428	5-3
412-R	0.0064567	5-3
416-R	0.02092	5-3
420-R	0.3041041	5-3
424-R	0.0450791	5-3
432-R	0.2061717	5-3
436-R	0.1636137	5-3
4-L	0.0695638	5-4
20-L	0.2031992	5-4
36-L	0.0453156	5-4
52-L	0.1274565	5-4
72-L	0.1862666	5-4
108-L	0.0212807	5-4
124-L	0.276188	5-4
136-L	0.1951889	5-4
152-L	0.0691042	5-4
168-L	0.0253994	5-4
208-L	0.157214	5-4
216-L	0.0136476	5-4
240-L	0.0063993	5-4
252-L	0.2446121	5-4
284-L	0.2427839	5-4
308-L	0.0958864	5-4
316-L	0.0240703	5-4
320-L	0.1725319	5-4
324-L	0.1475908	5-4

328-L	0.1075516	5-4
336-L	0.0673492	5-4
340-L	0.1700162	5-4
348-L	0.1034462	5-4
352-L	0.0324927	5-4
384-L	0.1395813	5-4
400-L	0.1656677	5-4
412-L	0.0114095	5-4
416-L	0.0601865	5-4
420-L	0.047138	5-4
424-L	0.0122125	5-4
432-L	0.1320307	5-4
436-L	0.1697985	5-4
4-R	0.0242619	5-4
20-R	0.2755014	5-4
36-R	0.1210522	5-4
52-R	0.1267705	5-4
108-R	0.1203608	5-4
124-R	0.1318017	5-4
136-R	0.1640663	5-4
168-R	0.0821593	5-4
208-R	0.143249	5-4
216-R	0.0869541	5-4
240-R	0.0448515	5-4
252-R	0.1624639	5-4
284-R	0.1542288	5-4
308-R	0.1368389	5-4
316-R	0.0366129	5-4
320-R	0.0315876	5-4
328-R	0.1563202	5-4
336-R	0.007345	5-4
340-R	0.1398114	5-4
348-R	0.3338569	5-4
352-R	0.0258651	5-4
400-R	0.0537745	5-4
412-R	0.1908374	5-4
416-R	0.1304287	5-4
420-R	0.0091531	5-4
424-R	0.1334078	5-4

432-R	0.1231093	5-4
436-R	0.0750718	5-4
4-L	0.0418855	5-6
20-L	0.1315784	5-6
36-L	0.1507936	5-6
52-L	0.2208129	5-6
72-L	0.1400425	5-6
108-L	0.0963361	5-6
124-L	0.0507996	5-6
136-L	0.1109803	5-6
152-L	0.0052629	5-6
168-L	0.0283887	5-6
208-L	0.2318055	5-6
216-L	0.0395889	5-6
240-L	0.1155637	5-6
252-L	0.058581	5-6
284-L	0.0146448	5-6
308-L	0.0995385	5-6
316-L	0.0563155	5-6
320-L	0.1043434	5-6
324-L	0.1475903	5-6
328-L	0.1004534	5-6
336-L	0.0638472	5-6
340-L	0.0183318	5-6
348-L	0.223791	5-6
352-L	0.3043331	5-6
384-L	0.0354751	5-6
400-L	0.02197	5-6
412-L	0.0622576	5-6
416-L	0.0469185	5-6
420-L	0.0045765	5-6
424-L	0.0279448	5-6
432-L	0.1865065	5-6
436-L	0.0090819	5-6
4-R	0.1771181	5-6
20-R	0.0466804	5-6
36-R	0.0162904	5-6
52-R	0.1485141	5-6
108-R	0.0247259	5-6

124-R	0.082605	5-6
136-R	0.0672779	5-6
168-R	0.1263114	5-6
208-R	0.1871802	5-6
216-R	0.0594957	5-6
240-R	0.0178567	5-6
252-R	0.0082572	5-6
284-R	0.0162484	5-6
308-R	0.0201524	5-6
316-R	0.3290463	5-6
320-R	0.0389003	5-6
328-R	0.1469139	5-6
336-R	0.1897215	5-6
340-R	0.0789503	5-6
348-R	0.1153296	5-6
352-R	0.0718547	5-6
400-R	0.1162421	5-6
412-R	0.1798555	5-6
416-R	0.0070464	5-6
420-R	0.1162471	5-6
424-R	0.0096366	5-6
432-R	0.2526219	5-6
436-R	0.0267737	5-6
4-L	0.0130824	6-1
20-L	0.1503361	6-1
36-L	0.2656655	6-1
52-L	0.3555892	6-1
72-L	0.0395979	6-1
108-L	0.0223253	6-1
124-L	0.0814616	6-1
136-L	0.1393546	6-1
152-L	0.1228796	6-1
168-L	0.0439367	6-1
208-L	0.2530805	6-1
216-L	0.2528481	6-1
240-L	0.032546	6-1
252-L	0.1414125	6-1
284-L	0.1876348	6-1
308-L	0.0801061	6-1

316-L	0.1968043	6-1
320-L	0.0864953	6-1
324-L	0.0572093	6-1
328-L	0.0370715	6-1
336-L	0.0929039	6-1
340-L	0.0359258	6-1
348-L	0.092216	6-1
352-L	0.3688607	6-1
384-L	0.100453	6-1
400-L	0.2759594	6-1
412-L	0.1526246	6-1
416-L	0.6512313	6-1
420-L	0.0679608	6-1
424-L	0.0021761	6-1
432-L	0.2160099	6-1
436-L	0.0025164	6-1
4-R	0.0965685	6-1
20-R	0.1446168	6-1
36-R	0.2210418	6-1
52-R	0.2036547	6-1
108-R	0.0730203	6-1
124-R	0.0066387	6-1
136-R	0.4416295	6-1
168-R	0.1031988	6-1
208-R	0.152167	6-1
216-R	0.1242535	6-1
240-R	0.1320304	6-1
252-R	0.3123523	6-1
284-R	0.111208	6-1
308-R	0.193127	6-1
316-R	0.1821437	6-1
320-R	0.0205982	6-1
328-R	0.0391306	6-1
336-R	0.284429	6-1
340-R	0.08375	6-1
348-R	0.1366085	6-1
352-R	0.1370702	6-1
400-R	0.2857984	6-1
412-R	0.0956483	6-1

416-R	0.5896741	6-1
420-R	0.1432552	6-1
424-R	0.1048005	6-1
432-R	0.0558325	6-1
436-R	0.0018626	6-1
4-L	0.10665	6-2
20-L	0.0146532	6-2
36-L	0.0035223	6-2
52-L	0.3123458	6-2
72-L	0.0878783	6-2
108-L	0.0471786	6-2
124-L	0.0070978	6-2
136-L	0.128599	6-2
152-L	0.259255	6-2
168-L	0.0711723	6-2
208-L	0.0556081	6-2
216-L	0.0492127	6-2
240-L	0.0167044	6-2
252-L	0.1384407	6-2
284-L	0.126769	6-2
308-L	0.0002628	6-2
316-L	0.1416421	6-2
320-L	0.1402683	6-2
324-L	0.4597042	6-2
328-L	0.0901654	6-2
336-L	0.0528591	6-2
340-L	0.051948	6-2
348-L	0.3368275	6-2
352-L	0.3551316	6-2
384-L	0.0954198	6-2
400-L	0.0343254	6-2
412-L	0.1723039	6-2
416-L	0.6887537	6-2
420-L	0.0219671	6-2
424-L	0.0355209	6-2
432-L	0.2588038	6-2
436-L	0.0514927	6-2
4-R	0.1119004	6-2
20-R	0.2340848	6-2

36-R	0.0720795	6-2
52-R	0.0950013	6-2
108-R	0.1814631	6-2
124-R	0.1018262	6-2
136-R	0.1196765	6-2
168-R	0.0931311	6-2
208-R	0.016543	6-2
216-R	0.005353	6-2
240-R	0.0432483	6-2
252-R	0.2052613	6-2
284-R	0.0594938	6-2
308-R	0.0874121	6-2
316-R	0.0588293	6-2
320-R	0.0192244	6-2
328-R	0.1789481	6-2
336-R	0.2816868	6-2
340-R	0.0613242	6-2
348-R	0.0297557	6-2
352-R	0.1494212	6-2
400-R	0.1613203	6-2
412-R	0.2043379	6-2
416-R	0.6503146	6-2
420-R	0.0748373	6-2
424-R	0.00352	6-2
432-R	0.0569875	6-2
436-R	0.0471398	6-2
4-L	0.0464534	6-3
20-L	0.0728015	6-3
36-L	0.2011343	6-3
52-L	0.0201363	6-3
72-L	0.0615543	6-3
108-L	0.0153365	6-3
124-L	0.0993087	6-3
136-L	0.0455356	6-3
152-L	0.2519328	6-3
168-L	0.1059473	6-3
208-L	0.1434715	6-3
216-L	0.2478141	6-3
240-L	0.0540031	6-3

252-L	0.1393554	6-3
284-L	0.4805272	6-3
308-L	0.0627076	6-3
316-L	0.0432528	6-3
320-L	0.0746023	6-3
324-L	0.1073239	6-3
328-L	0.0480539	6-3
336-L	0.0560614	6-3
340-L	0.2404971	6-3
348-L	0.0546897	6-3
352-L	0.36726	6-3
384-L	0.004353	6-3
400-L	0.368404	6-3
412-L	0.0716213	6-3
416-L	0.1626952	6-3
420-L	0.2608575	6-3
424-L	0.0411941	6-3
432-L	0.1713945	6-3
436-L	0.1663536	6-3
4-R	0.033648	6-3
20-R	0.2823666	6-3
36-R	0.2029657	6-3
52-R	0.0327542	6-3
108-R	0.0176729	6-3
124-R	0.0892411	6-3
136-R	0.0029397	6-3
168-R	0.0473675	6-3
208-R	0.1109786	6-3
216-R	0.2812229	6-3
240-R	0.0695655	6-3
252-R	0.1588029	6-3
284-R	0.0954218	6-3
308-R	0.3704711	6-3
316-R	0.3221811	6-3
320-R	0.0017694	6-3
328-R	0.0129883	6-3
336-R	0.2377564	6-3
340-R	0.1038898	6-3
348-R	0.0594939	6-3

352-R	0.1567444	6-3
400-R	0.0119111	6-3
412-R	0.1734538	6-3
416-R	0.0139646	6-3
420-R	0.4203468	6-3
424-R	0.0354825	6-3
432-R	0.0464508	6-3
436-R	0.13684	6-3
4-L	0.0277278	6-4
20-L	0.0716741	6-4
36-L	0.1054927	6-4
52-L	0.0933636	6-4
72-L	0.0462242	6-4
108-L	0.0750554	6-4
124-L	0.2253894	6-4
136-L	0.0842086	6-4
152-L	0.0638413	6-4
168-L	0.0537794	6-4
208-L	0.0745959	6-4
216-L	0.0261304	6-4
240-L	0.1093771	6-4
252-L	0.1860323	6-4
284-L	0.2574277	6-4
308-L	0.195416	6-4
316-L	0.0322647	6-4
320-L	0.0681925	6-4
324-L	0.0007653	6-4
328-L	0.0071288	6-4
336-L	0.0041439	6-4
340-L	0.1517187	6-4
348-L	0.1203624	6-4
352-L	0.2718404	6-4
384-L	0.1041159	6-4
400-L	0.1437001	6-4
412-L	0.0734544	6-4
416-L	0.0134001	6-4
420-L	0.0425619	6-4
424-L	0.0160178	6-4
432-L	0.3185268	6-4

436-L	0.1608622	6-4
4-R	0.1528585	6-4
20-R	0.322181	6-4
36-R	0.137293	6-4
52-R	0.0217497	6-4
108-R	0.0956485	6-4
124-R	0.2144067	6-4
136-R	0.0967917	6-4
168-R	0.044169	6-4
208-R	0.043934	6-4
216-R	0.0274781	6-4
240-R	0.0270203	6-4
252-R	0.1542289	6-4
284-R	0.1379813	6-4
308-R	0.1166992	6-4
316-R	0.3656572	6-4
320-R	0.0704796	6-4
328-R	0.009512	6-4
336-R	0.1967915	6-4
340-R	0.0608681	6-4
348-R	0.2185276	6-4
352-R	0.0460169	6-4
400-R	0.1700146	6-4
412-R	0.3706925	6-4
416-R	0.1373058	6-4
420-R	0.107094	6-4
424-R	0.1430254	6-4
432-R	0.1295134	6-4
436-R	0.0483007	6-4
4-L	0.0418855	6-5
20-L	0.1315784	6-5
36-L	0.1507936	6-5
52-L	0.2208129	6-5
72-L	0.1400425	6-5
108-L	0.0963361	6-5
124-L	0.0507996	6-5
136-L	0.1109803	6-5
152-L	0.0052629	6-5
168-L	0.0283887	6-5

208-L	0.2318055	6-5
216-L	0.0395889	6-5
240-L	0.1155637	6-5
252-L	0.058581	6-5
284-L	0.0146448	6-5
308-L	0.0995385	6-5
316-L	0.0563155	6-5
320-L	0.1043434	6-5
324-L	0.1475903	6-5
328-L	0.1004534	6-5
336-L	0.0638472	6-5
340-L	0.0183318	6-5
348-L	0.223791	6-5
352-L	0.3043331	6-5
384-L	0.0354751	6-5
400-L	0.02197	6-5
412-L	0.0622576	6-5
416-L	0.0469185	6-5
420-L	0.0045765	6-5
424-L	0.0279448	6-5
432-L	0.1865065	6-5
436-L	0.0090819	6-5
4-R	0.1771181	6-5
20-R	0.0466804	6-5
36-R	0.0162904	6-5
52-R	0.1485141	6-5
108-R	0.0247259	6-5
124-R	0.082605	6-5
136-R	0.0672779	6-5
168-R	0.1263114	6-5
208-R	0.1871802	6-5
216-R	0.0594957	6-5
240-R	0.0178567	6-5
252-R	0.0082572	6-5
284-R	0.0162484	6-5
308-R	0.0201524	6-5
316-R	0.3290463	6-5
320-R	0.0389003	6-5
328-R	0.1469139	6-5

336-R	0.1897215	6-5
340-R	0.0789503	6-5
348-R	0.1153296	6-5
352-R	0.0718547	6-5
400-R	0.1162421	6-5
412-R	0.1798555	6-5
416-R	0.0070464	6-5
420-R	0.1162471	6-5
424-R	0.0096366	6-5
432-R	0.2526219	6-5
436-R	0.0267737	6-5

Appendix D: Basic Statistics and Anderson-Darling Output

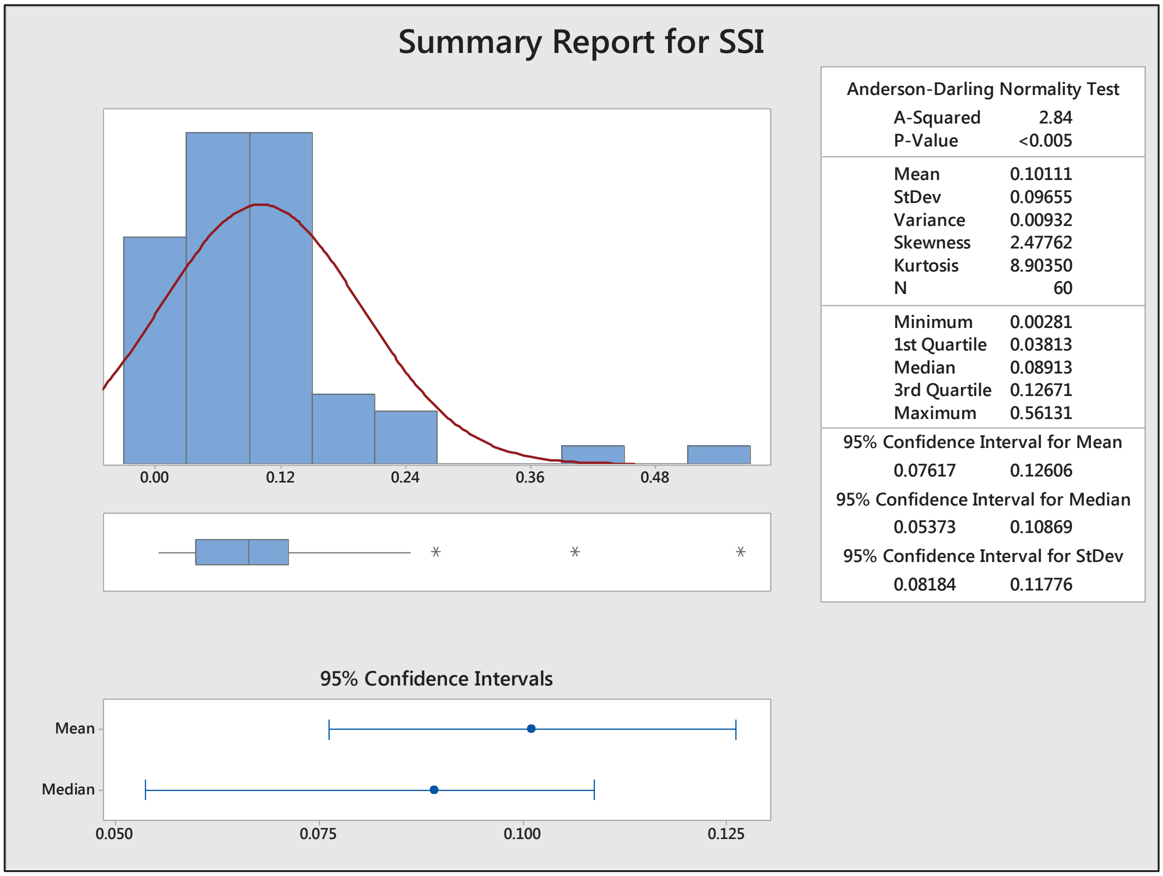

Figure A.1 Summary Report for SSI (V1-V2)

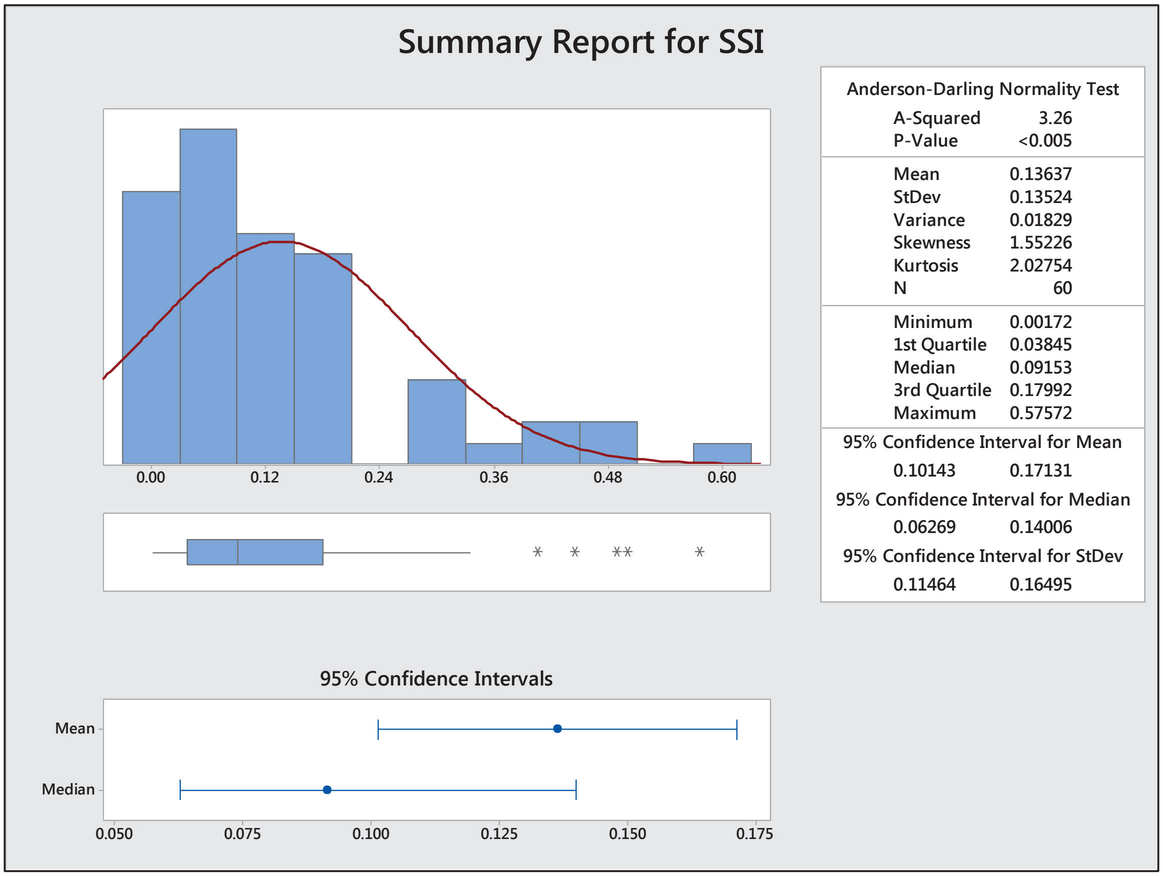

Figure A.2 Summary Report for SSI (V1-V3)

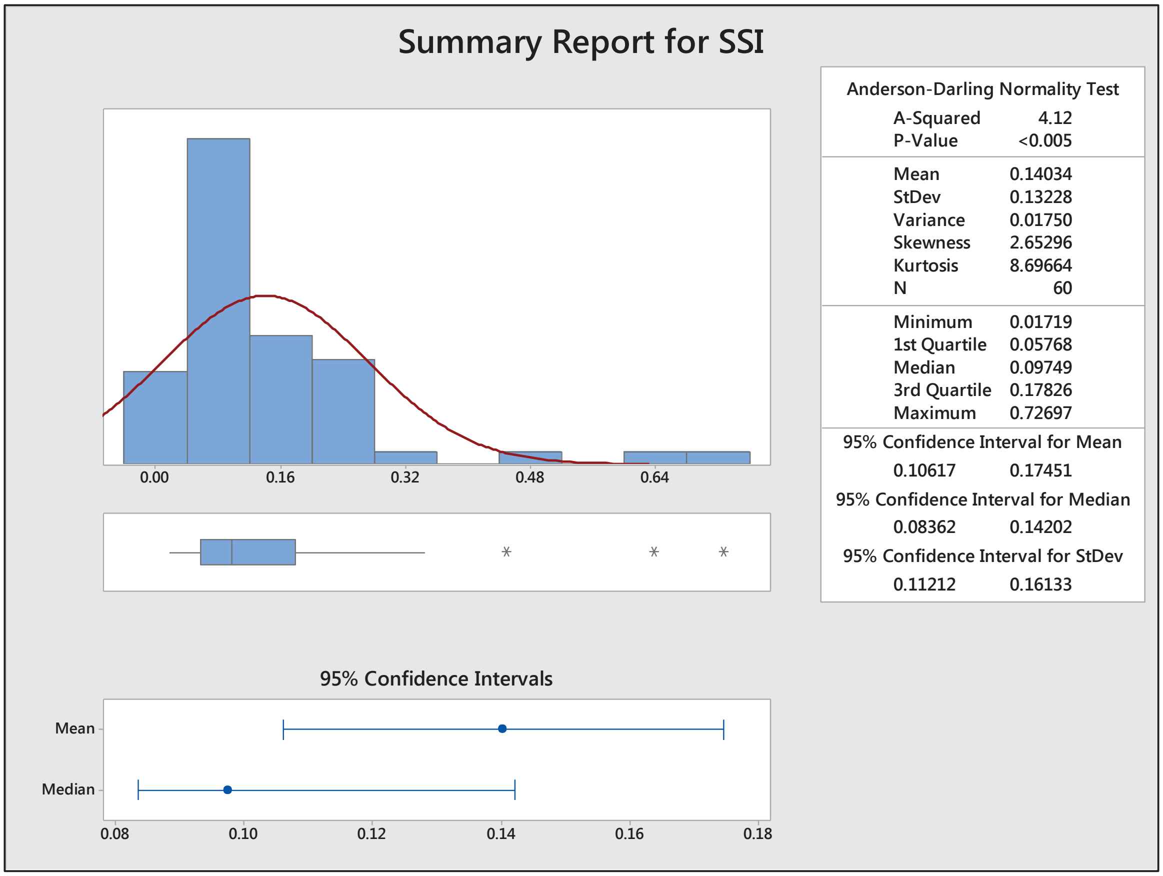

Figure A.3 Summary Report for SSI (V1-V4)

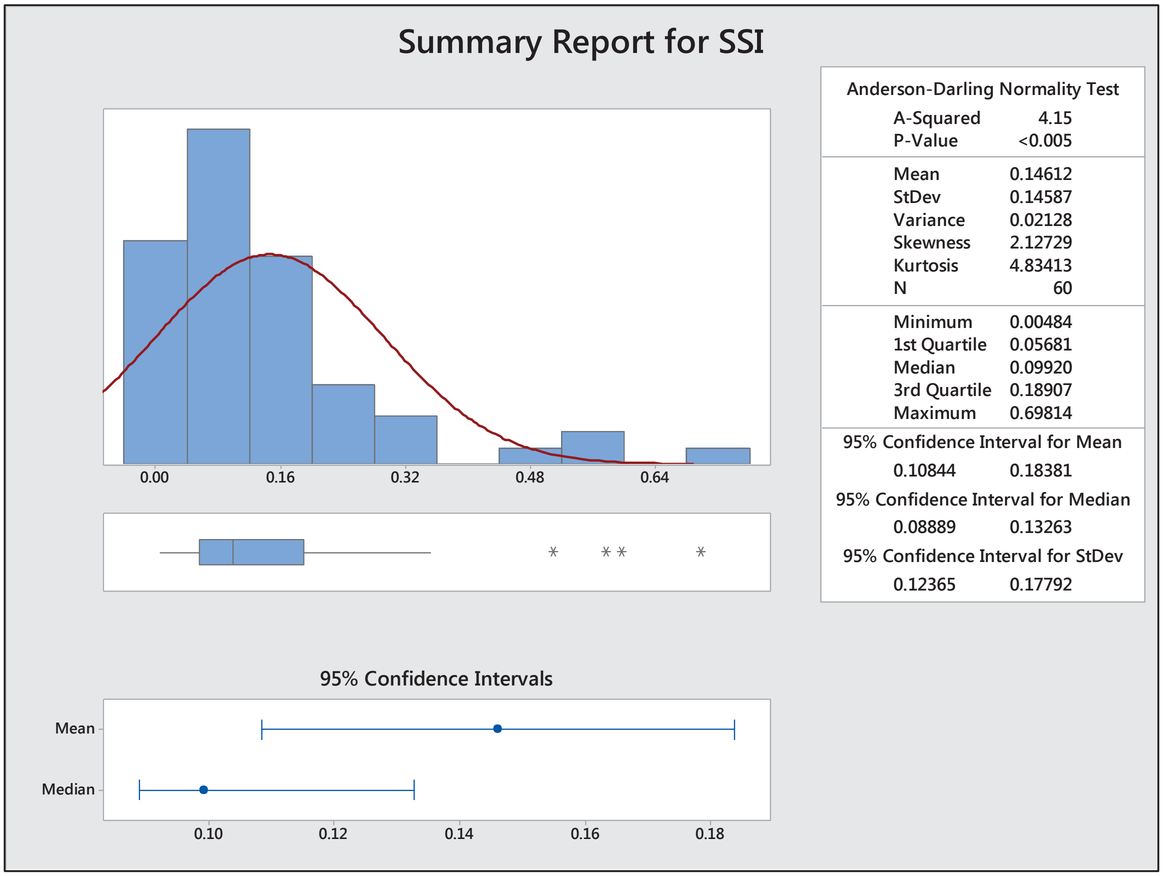

Figure A.4 Summary Report for SSI (V1-V5)

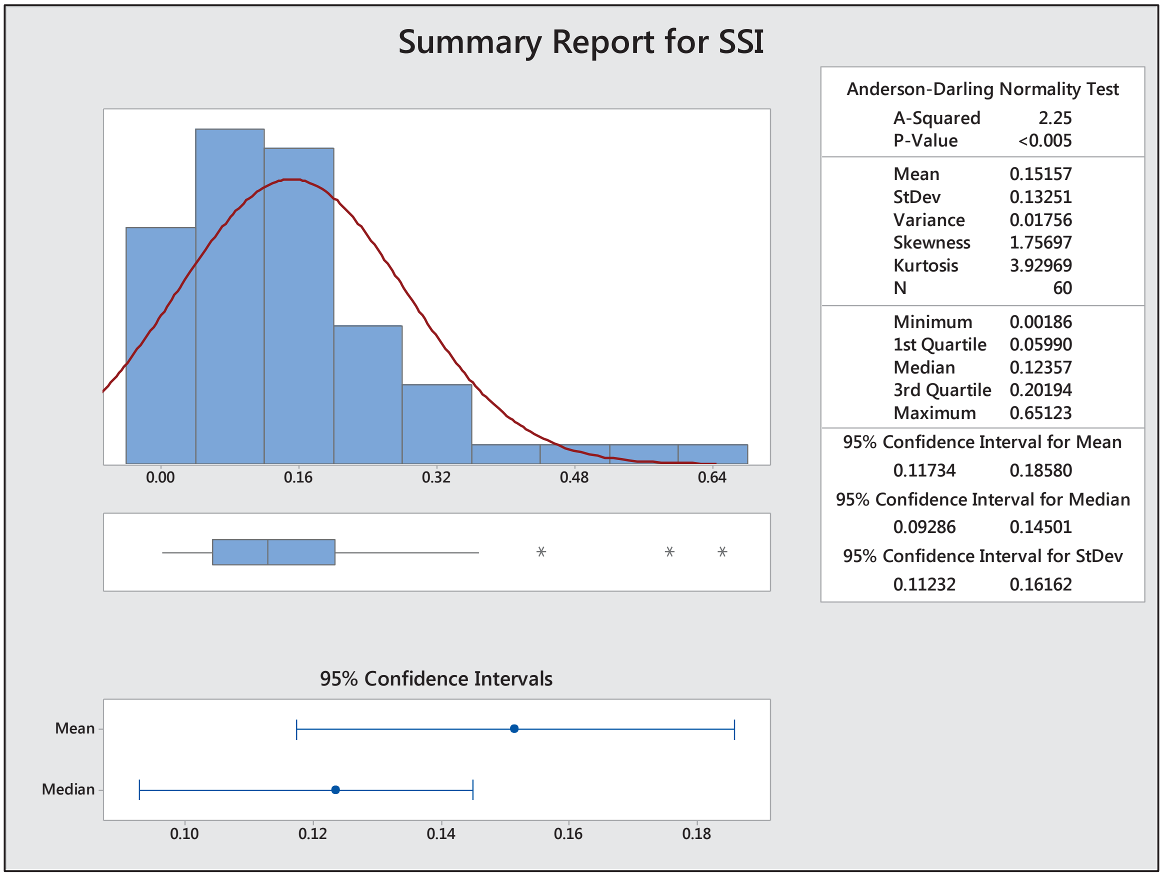

Figure A.5 Summary Report for SSI (V1-V6)

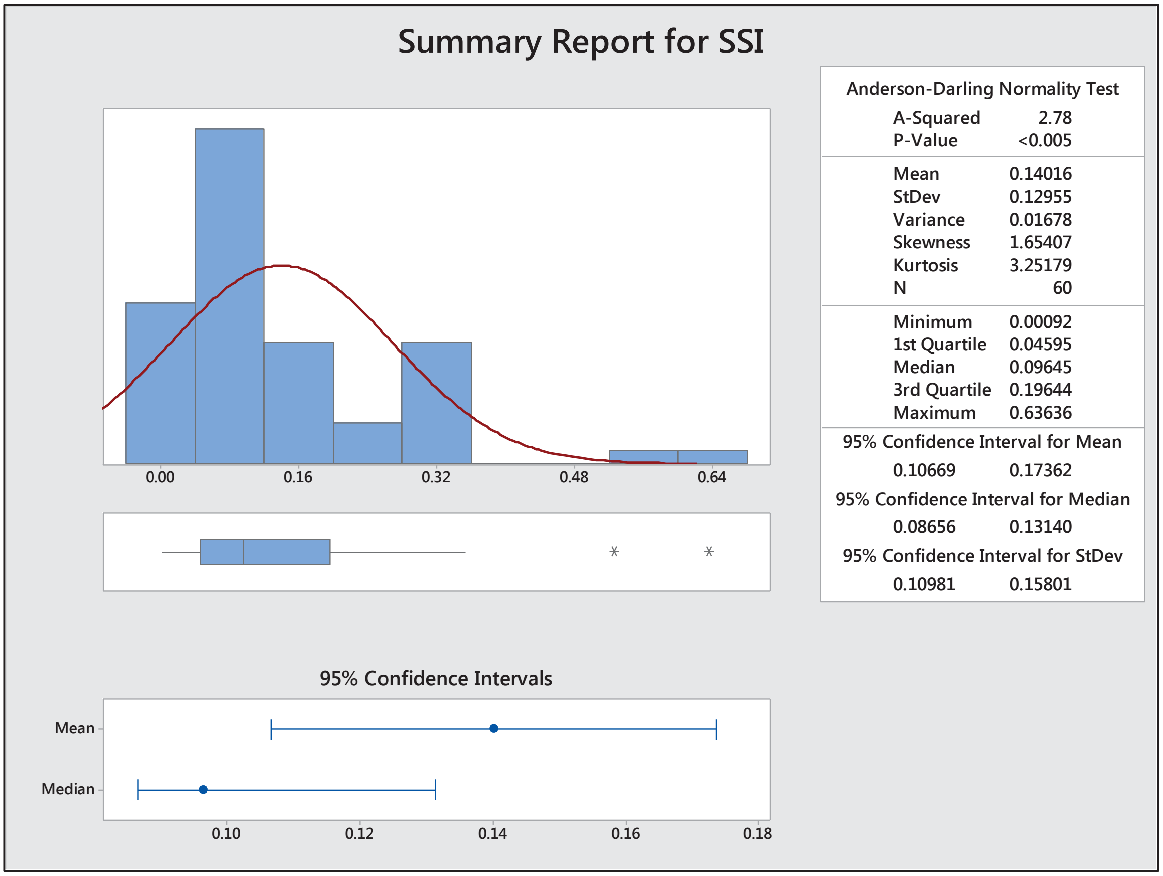

Figure A.6 Summary Report for SSI (V2-V3)

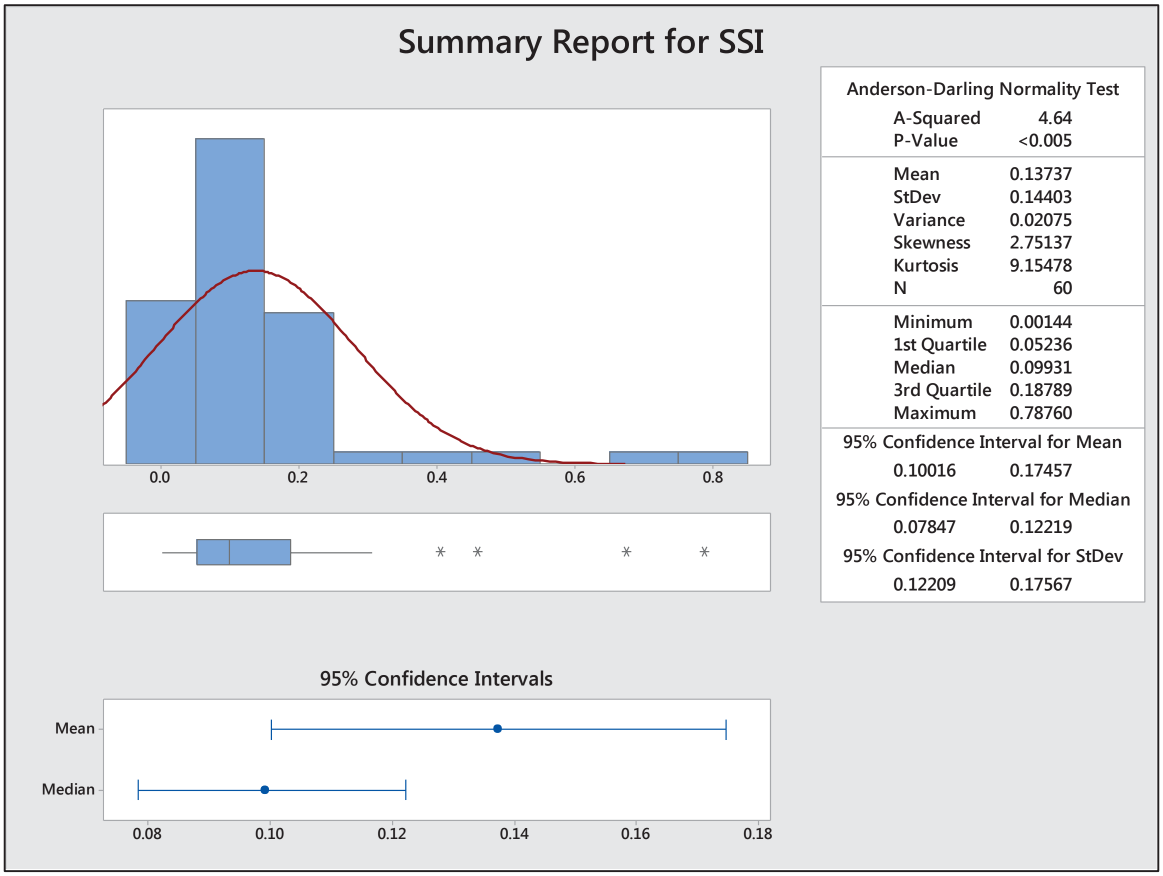

Figure A.7 Summary Report for SSI (V2-V4)

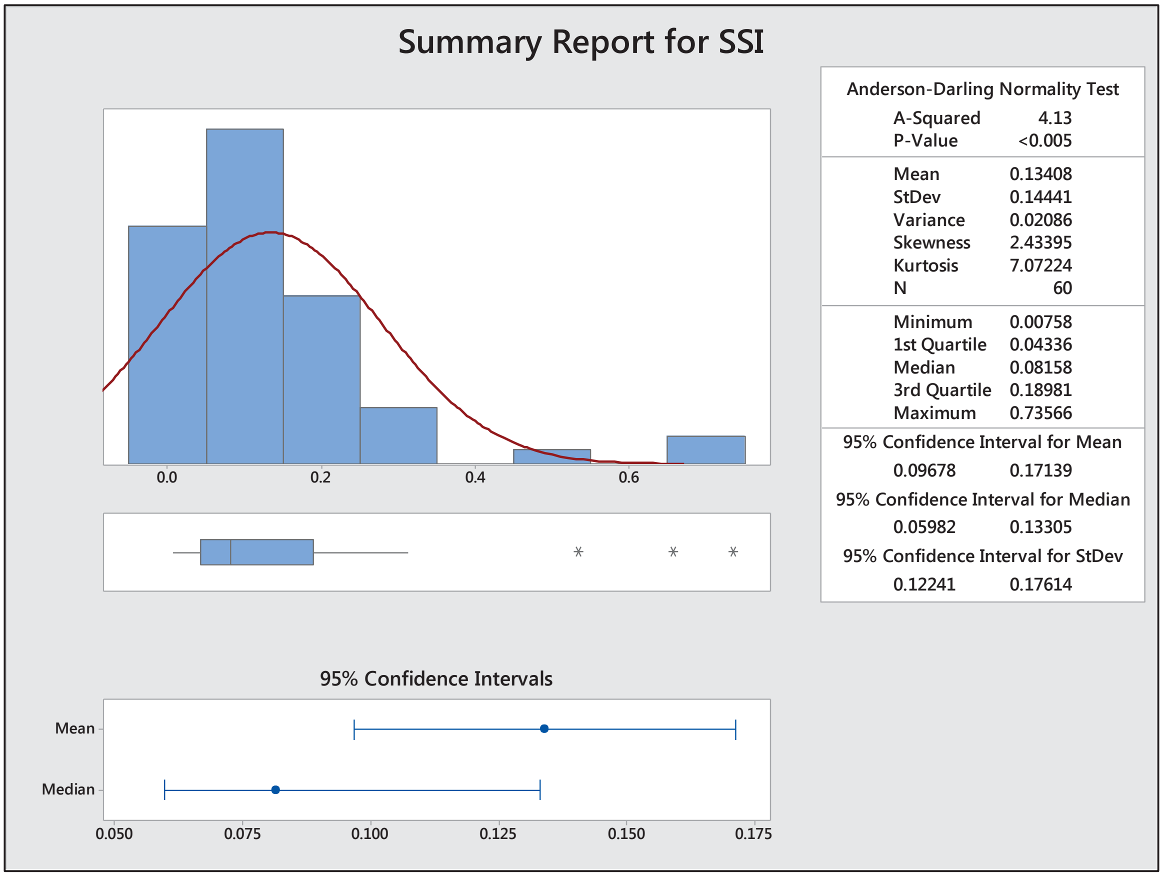

Figure A.8 Summary Report for SSI (V2-V5)

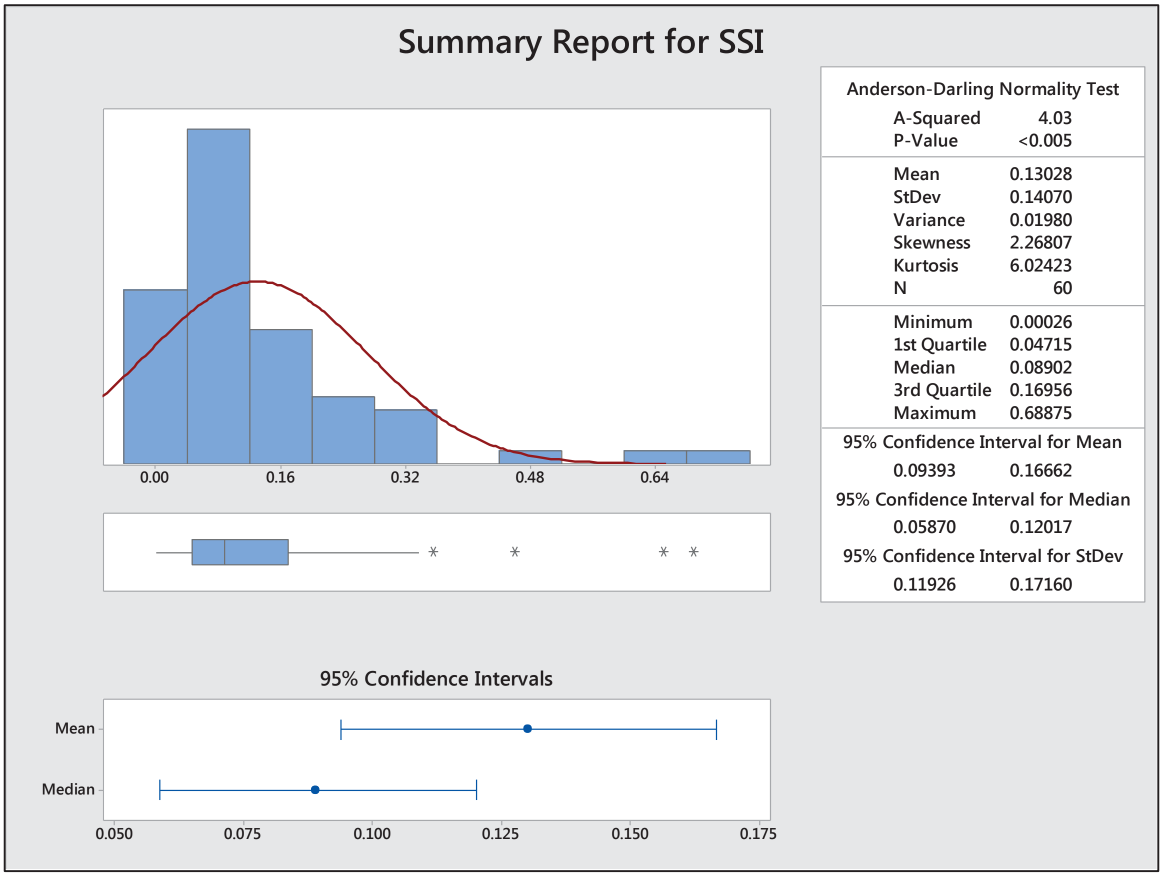

Figure A.9 Summary Report for SSI (V2-V6)

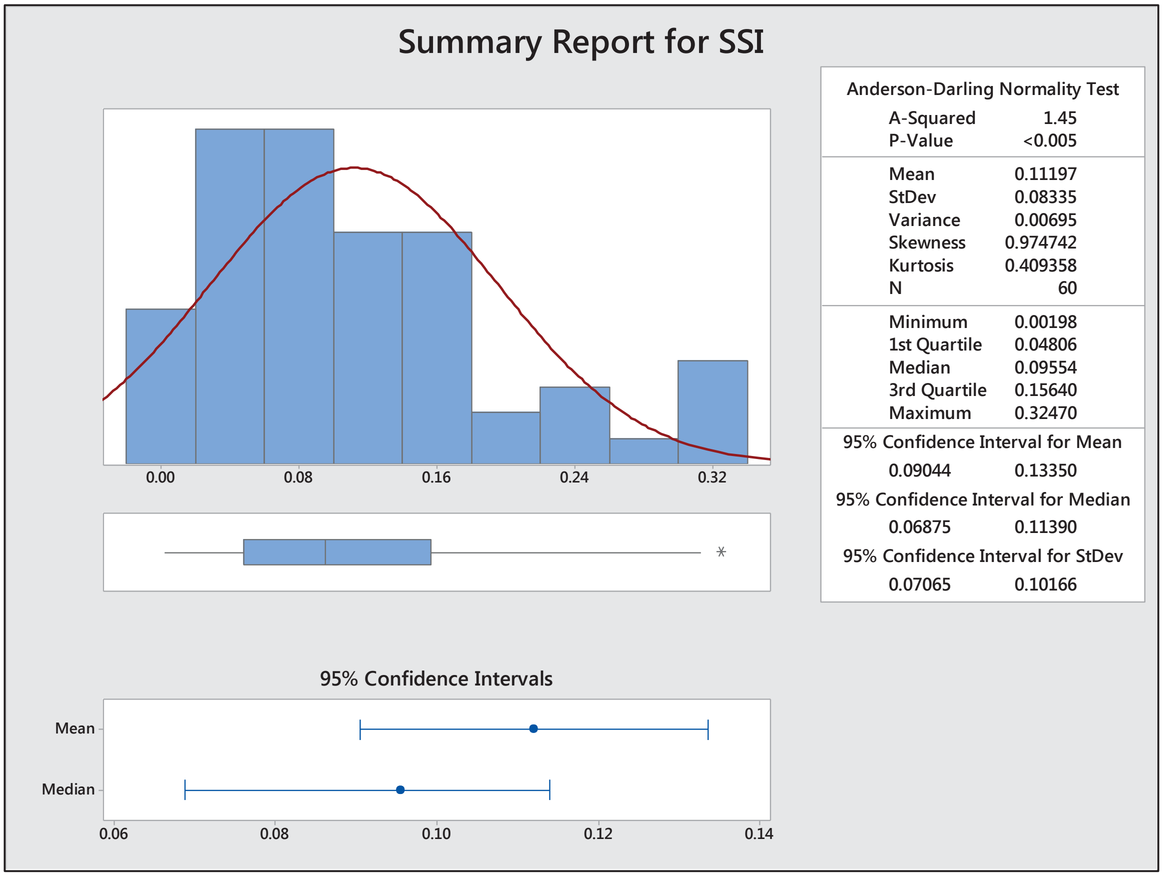

Figure A.10 Summary Report for SSI (V3-V4)

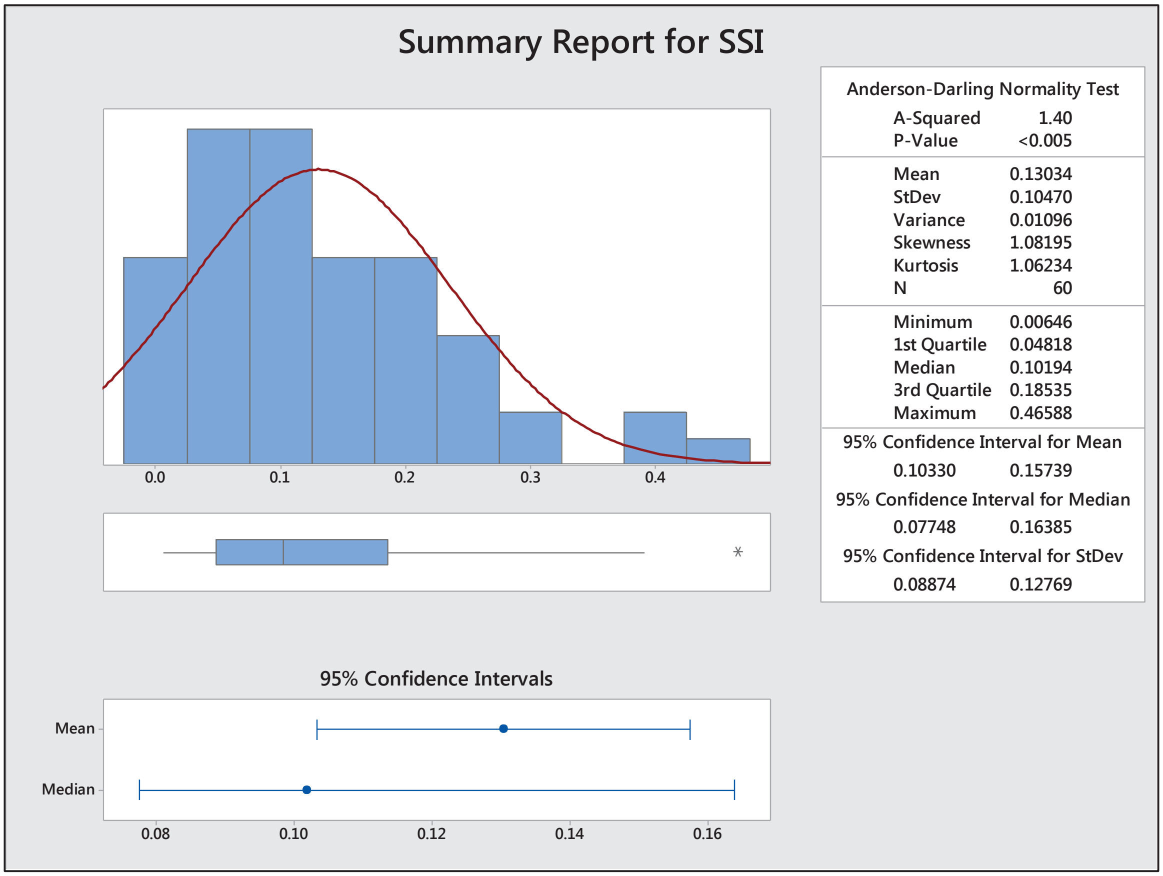

Figure A.11 Summary Report for SSI (V3-V5)

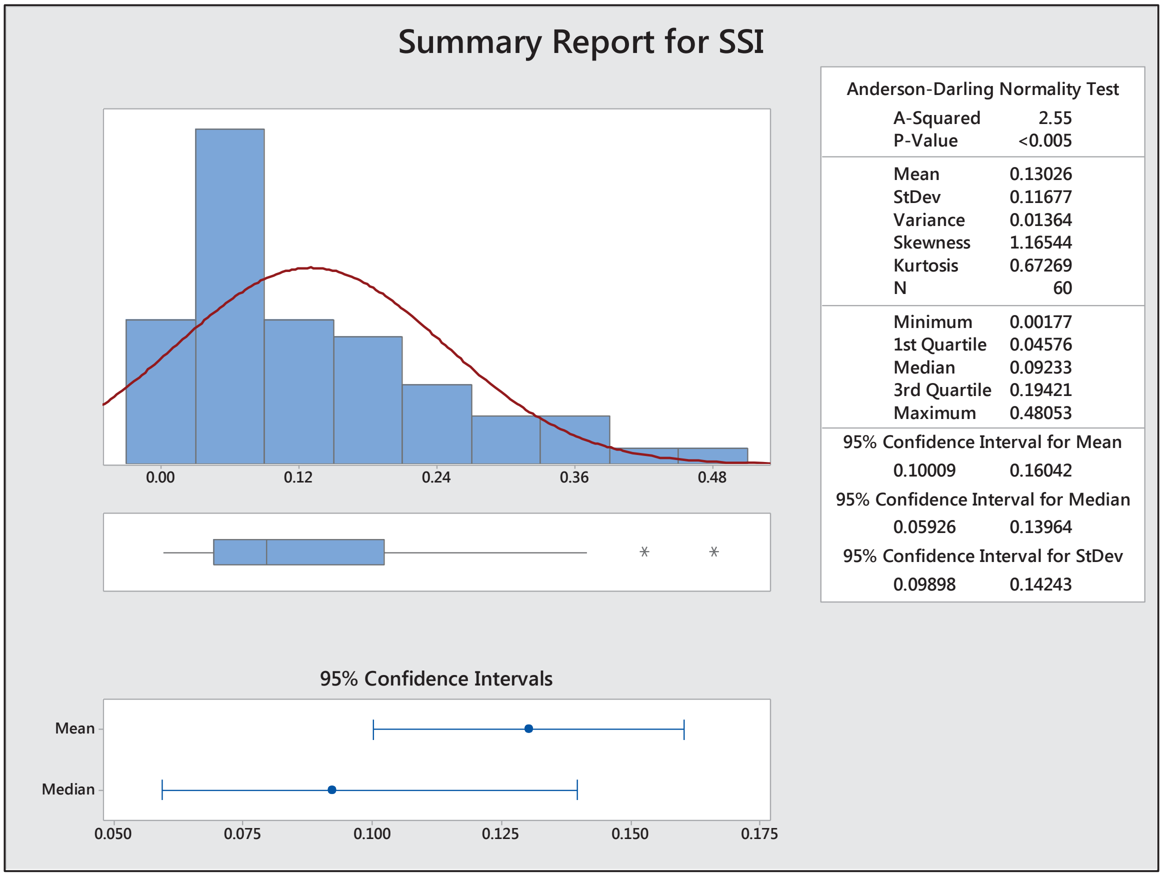

Figure A.12 Summary Report for SSI (V3-V6)

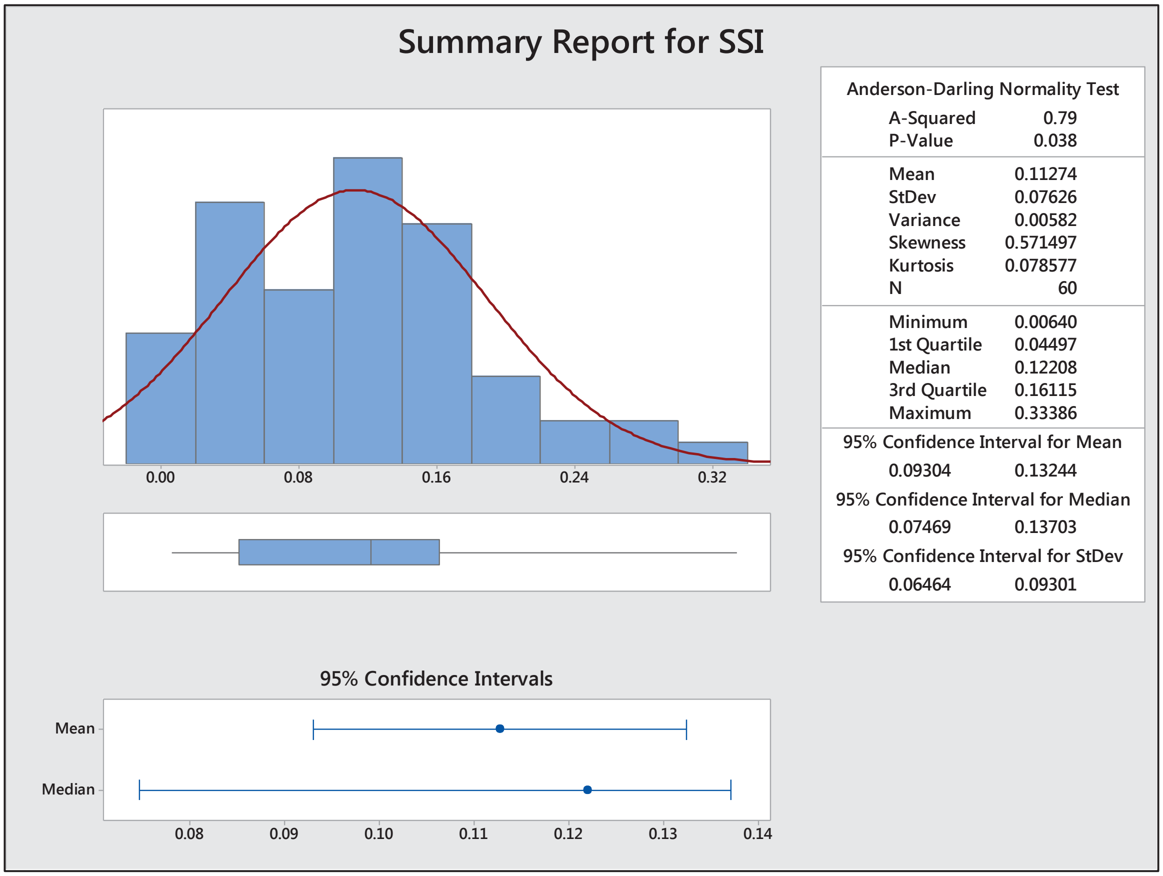

Figure A.13 Summary Report for SSI (V4-V5)

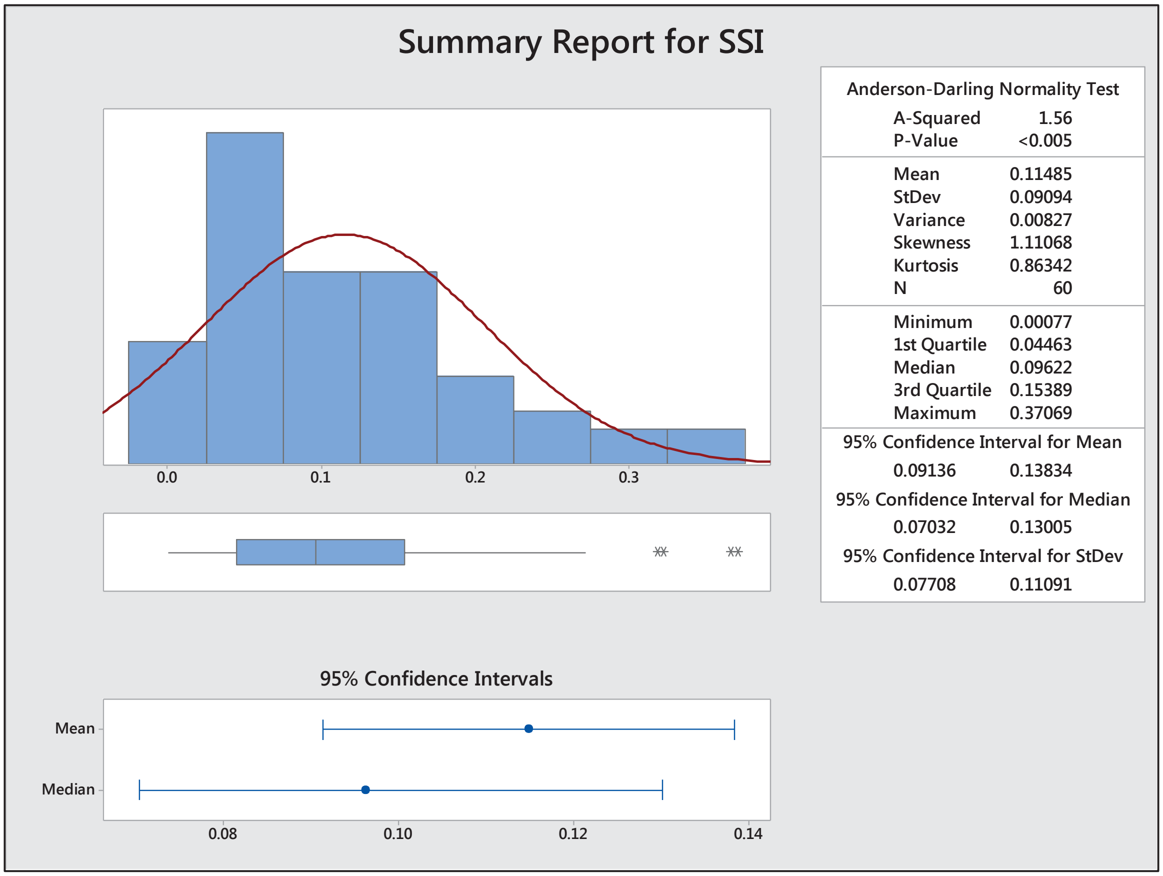

Figure A.14 Summary Report for SSI (V4-V6)

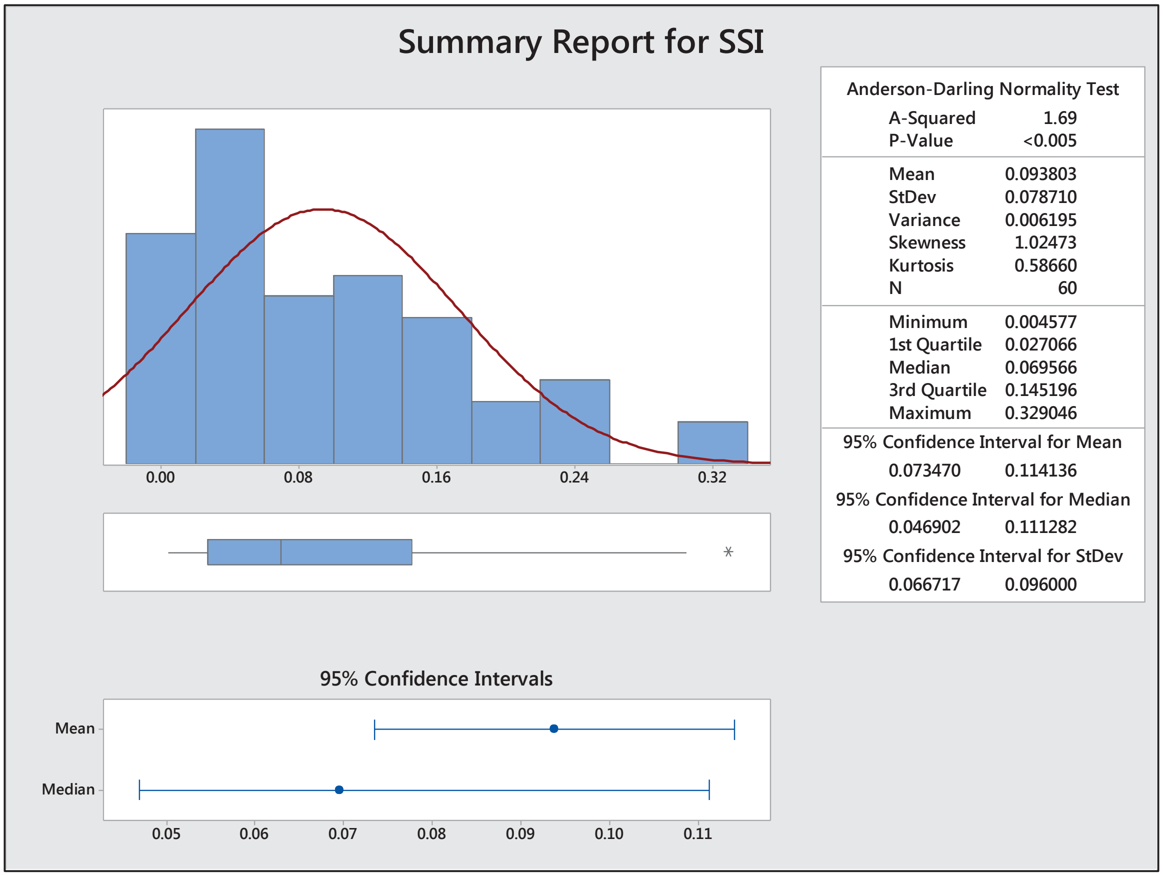

Figure A.15 Summary Report for SSI (V5-V6)