A Close Look at the Significance of Margin Drift: What Does It Really Tell Us?

Robert F. Bey [1] and Dennis J. Ryan [2]

[1] John Jay College of Criminal Justice, New York, NY
[2] Nassau County Police Department Scientific Investigation Bureau, Mineola, New York

Many times the Forensic Document Examiner (FDE) is called upon to examine documents where there are multiple signatures of one individual. The question put forth to us as experts is, "Were these signatures executed at one sitting or were these signatures written on different occasions?" In order to answer this question, an FDE may look at a phenomenon called "margin drift" and use this as a factor in arriving at their conclusion. The critical problem that arises for the FDE is: How much weight do we give to this phenomenon? Moreover, can margin drift be a significant factor in indicating that a group of signatures were written during one sitting? This is the problem put forth in this paper.

Introduction

Questions about the execution of the signatures arise, for example, when the questioned document is a sign-in sheet from a medical clinic. Very often the correct procedure in these clinics is for the patient to sign-in on the same sheet each day they receive treatment. The genuine document will be a sheet of lined paper with the numeric date listed on the left side of the paper. The patient's signatures will appear on each day of that month that they received treatment. Each signature, therefore, is signed on separate occasions corresponding to the single day the patient received billable treatment.

The allegation in these types of cases is that the patient was given a sum of money by the medical clinic. In return, the patient is expected to sit down and fill out multiple sign-in sheets, signing their names numerous times consecutively, during *one* sitting and *one* visit. The patient would leave and never receive any billable treatment from the clinic of any kind. The clinic in turn would use these signature sign-in sheets as proof that the patient was present for treatment on a given day that month. The clinic would then submit these to the insurance companies for payment.

As stated previously, the question that is asked is, "Were these signatures executed at one sitting or were they written on different occasions?" In the context of these cases involving the sign-in sheets, the foregoing question is revised slightly. The insurance investigator is usually only interested in the question "Were the signatures written on different dates as indicated or were they not written on as indicated?" This study was formulated such that the observed results would indicate whether margin drift is a tell-tale sign that a series of *consecutive* signatures, written in a single column, were written during one interval of time.

Methods and Materials

Before we begin exploring this problem of margin drift and its significance, we must derive a general definition of margin drift. Margin drift as we have defined it for this paper is *the unconscious movement away from the left side starting point in multiple lines of writing in columnar form* (Figure 1). For the purposes of this paper, we subdivided this movement into three degrees: Extreme, Mild and Moderate.

Our hypothesis is that margin drift is not significant and is not prevalent in writers when asked to give multiple specimens of their signature at one sitting. Therefore, if a series of consecutive signatures displays the previously defined margin drift, the Forensic Document Exam-

iner (FDE) cannot readily conclude that the author wrote the signatures during one sitting based solely upon the existence of margin drift.

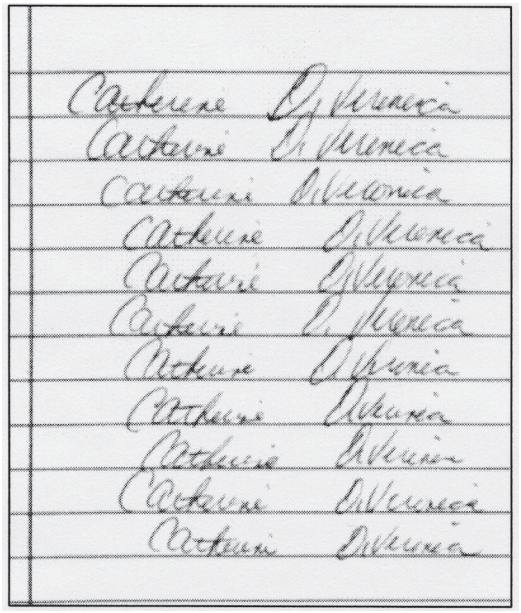


Figure 1. Appearance of Basic Margin Drift

Purpose of Study

The purpose of this study is to:

1. Determine the prevalence of margin drift.

2. Find ways of measuring various degrees of margin drift in a manner easily used by all Forensic Document Examiners.

3. Determine if certain factors influence the presence or degree of drift.

4. Determine whether margin drift can be used as an analytical tool in identifying a series of consecutive signatures as being written during one sitting.

Description of the Sign-In Sheets

The only materials that are necessary for this experimental procedure are two separate pieces of paper for each subject. We attempted to replicate the medical sign–in sheets. These sheets are described below:

Sheet #1

The sheet was created on a word-processing program on a computer. A chart was formed where each of the boundaries of the chart contained a solid border line. After printing, the result is a form similar to a common piece of lined paper (Figure 2).

The exact specifications of the chart:
Number of rows: 21
Width of chart: 20cm
Number of columns: 2
Length of chart: 22.5cm
Size of *right* column: 17.5cm
Size of TOP row: 3cm
Size of *left* column: 2.5cm
Size of remaining 20 rows: 1cm

At 1.5cm above the top of the chart are two regions:

1. A labeled space to write ID

2. Two check boxes, one labeled "Left Handed" and the other "Right Handed."

Sheet #2

Sheet #2 (Figure 3) is exactly the same as Sheet #1: Size of chart, number of rows, and the information spaces at the top. However, there are two important differences:

1. Sheet #2 has only ONE (1) column. There fore, the single column is the same size as the chart, 20.0cm.

2. On the TOP row, the following is written 3.0cm from the left side of the chart exactly as shown:

   Please Sign Your
   Full Name Below

The collection of handwriting samples

The methodology we used for this research was to collect handwriting samples from numerous people. The subjects chosen were all adults, ranging in age from 18-65. The signatures were collected at either the individual's workplace or at his/her school (for the individuals who are college students). The collection phase was separated in two distinct processes: (1) 12 signatures signed on each sheet during one sitting, without break, (2) 12 signatures signed on each sheet where there was a considerable period of time between signatures. (Note: The subjects that participated did not necessarily participate in both parts of the collection process.) A more detailed account of the collection process is described.

Signatures written during one sitting

The subjects were given the two prepared sheets one at a time. Sheet #1 contained a solid margin line, 2.50 cm. from the left edge of the paper, similar to the one seen on common loose-leaf paper (Figure 2). The boundary between the two columns serves as the margin line for the 2.50 cm left margin on the sheet. On the second sheet of paper (Figure 3) only one column is present, therefore, there is no margin line present. Instead, at the top of the form appeared typed writing that was included in an attempt to make the starting point for each subject somewhat similar, enabling more accurate comparisons during the analysis of the data.

Figure 2. Sheet #1 contains a continuous margin line on the left side of the form, similar to that of common loose-leaf paper.

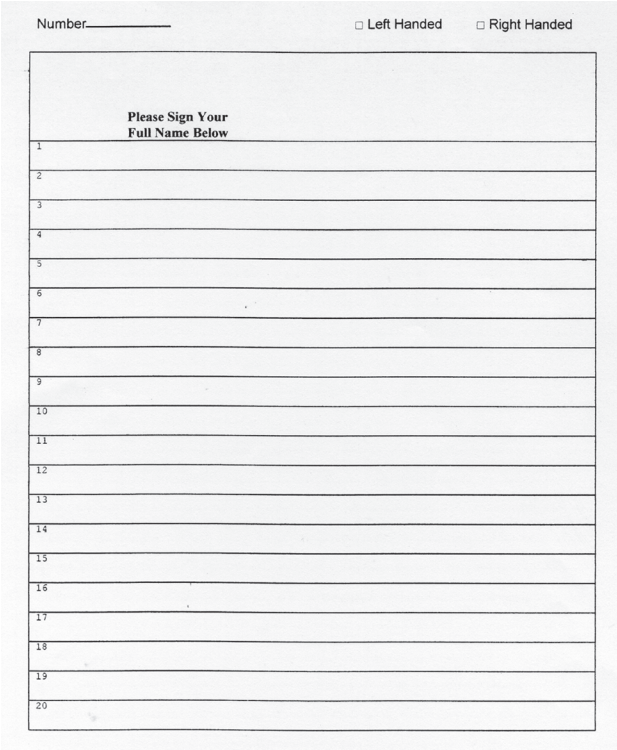


Figure 3. Sheet #2 does not have a margin line present along the left side of the paper. Notice that each of the two forms is identical except for the presence of a margin line and text at the top of the form.

The instructions

The instructions given to each subject were: "After indicating your handedness by checking the appropriate box, sign your name 12 times in a single column, one right after another, without skipping any lines, starting from the first full line." The subjects were instructed to sign their signatures as they customarily would on a credit card or bank form. The form containing the margin line was used first. Upon the completion of the twelve signatures, the person returned the sheet of paper.

The subject was then handed the form *without* the margin line and another 12 signatures were written on twelve consecutive lines. This form was also collected from the individual. The signatures were written on either a desk or a table while the subject was sitting down.

A total of 131 subjects were tested, each signing their name a total of 24 times (12 on each sheet) for an overall total of 3,144 signatures collected.

Signatures written on separate occasions

Again, the subjects were given the sheets one at a time and were instructed to designate his/her handedness by checking the appropriate box at the top of each sheet. Each subject was requested to sign his/her name one at a time, 12 times, without skipping lines, with an *extended period of time* between signatures on each sheet. The circumstances of the individual dictated the actual collection process. For example, a set of 40 people who participated in the study signed his/her name during their normal workday. Each individual would sign his/her name 4 times per sheet, per day: twice in the morning (once on each sheet), twice before lunch break, twice after lunch break, and twice before leaving. Therefore, the collection of the 24 total signatures per individual was completed after 3 days. The other subjects tested signed their signatures at varying times, occasions, and rates due to differing controlling factors. For instance, some of the subjects were college students. The student would sign his/her name over a longer period of time due to the more sporadic frequency of time spent in school (once, twice, three times a week) where the signatures were composed. However, each and every subject signed their signatures over a period of time where no more than 4 signatures were authored per sheet per hour. A total of 70 individuals participated, resulting in 1,680 signatures collected when they were written over an interval of time.

Results

Each sheet was organized and filed appropriately. Next, each series of signatures was observed for the presence of margin drift. In order to group a series of signatures into one of the three degrees of drift (Extreme, Mild, Moderate), basic parameters need to be formulated for each category. These parameters serve to support consistency, reliability, and reproducibility of results.

Measuring the degree of drift is accomplished by first drawing a perpendicular line originating through the starting point of the first signature of the series down to one full line below the last signature. This line will serve as the theoretical line with which the left side of each signature would line up if no margin drift were present. A second line is then drawn which also originates through the starting point of the first signature of the series. This line follows the left side of the column of signatures, down to one full line below the last signature. This line should intersect the starting point of *each* signature as closely as possible. This second line will obviously be at some angle to the original perpendicular line if margin drift is present. Since both lines originated from the same point, an angle is formed. The magnitude of this characteristic angle is directly proportional to the degree of margin drift present. As the degree of drift becomes more extreme, the angle measure also increases accordingly. Conversely, as the degree of drift becomes less drastic, this angle measure will thereby decrease. Finally, a third line is drawn connecting the ends of the two previous lines at the line below the last signature. Since the distance of the third line is dependent on the previously decried angle, this measure is also directly related to the degree of margin drift. As the angle increases so does the distance of the third line. Hence, greater third line distance indicates more drastic margin drift. The distance of this line is measured and this value is used as the degree of drift from the theoretical perpendicular. Those signatures that drifted a minimum of 0.5 cm and a maximum drift of 0.8 cm are classified as **Mild**. Those signatures that drifted more than 1.10cm are classified as **Extreme**. A distance separation anywhere between these two parameters ($0.8\text{ cm} < x < 1.10\text{ cm}$) is considered **Moderate**. Therefore, in order to conclude that a series of signatures exhibit mar-

gin drift there should be a minimum distance separation of 0.5 cm.

(Figures 4-7 depict No Drift, Mild, Moderate, and Extreme Drift.)

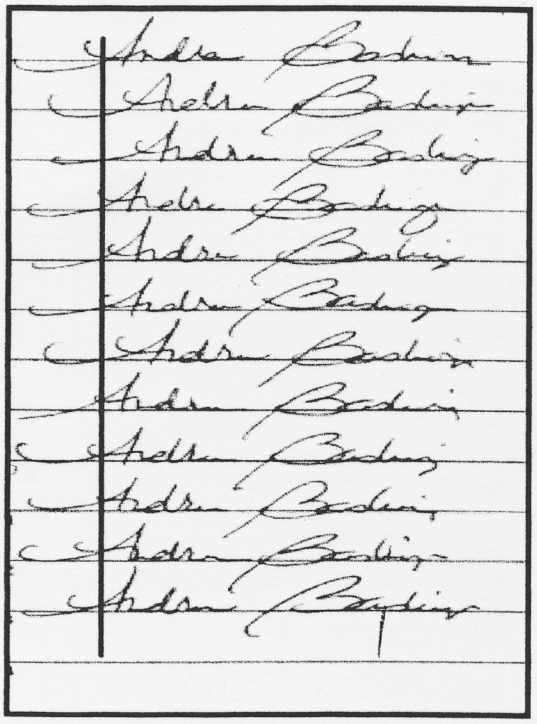


Figure 4. No margin drift (1:1)

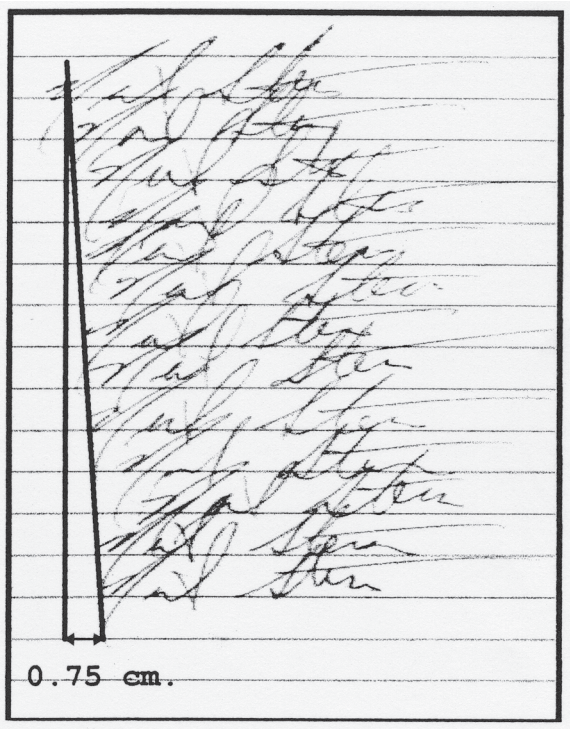


Figure 5. Mild margin drift (1:1)

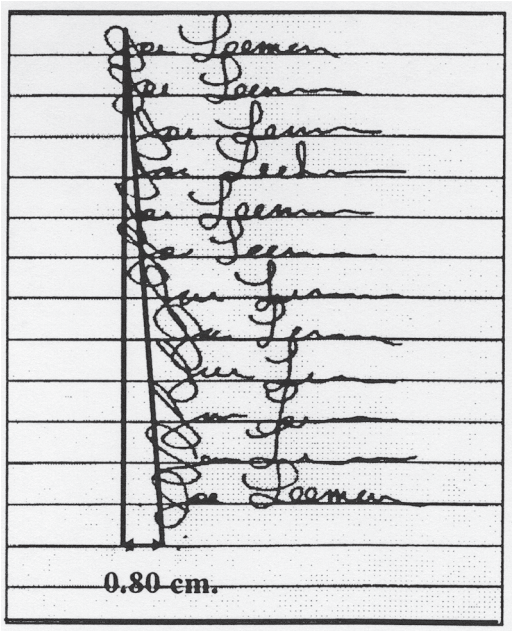


Figure 6. Moderate margin drift (1:1)

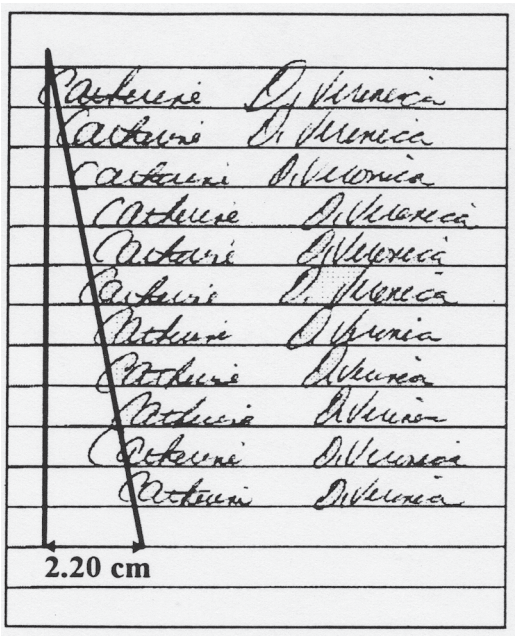
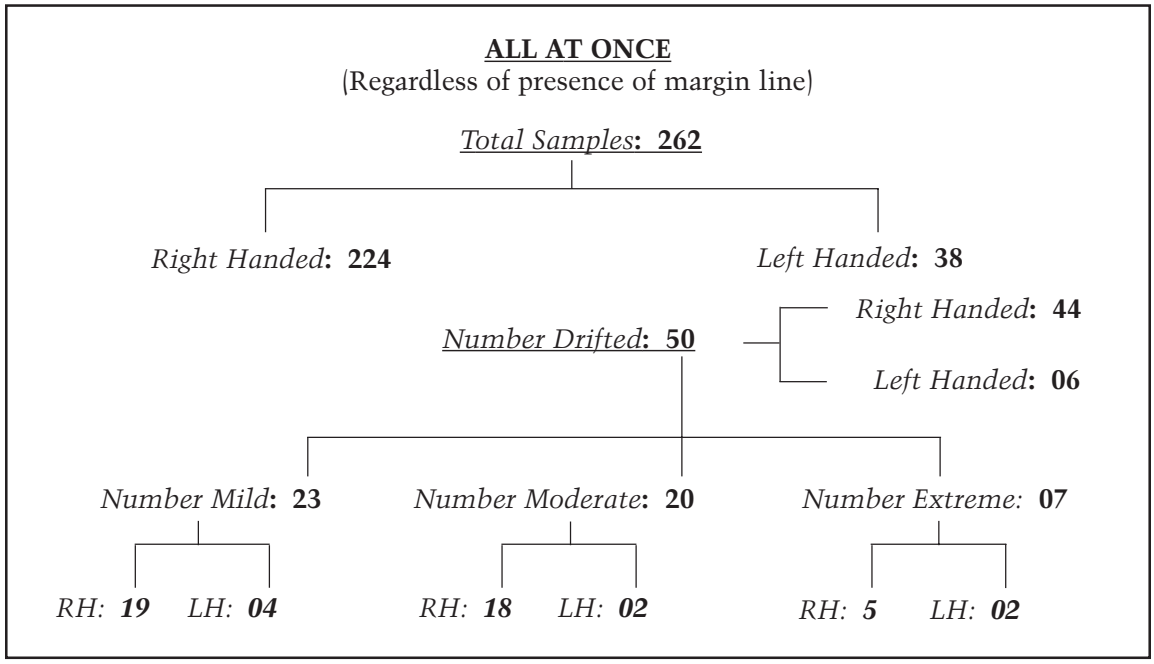


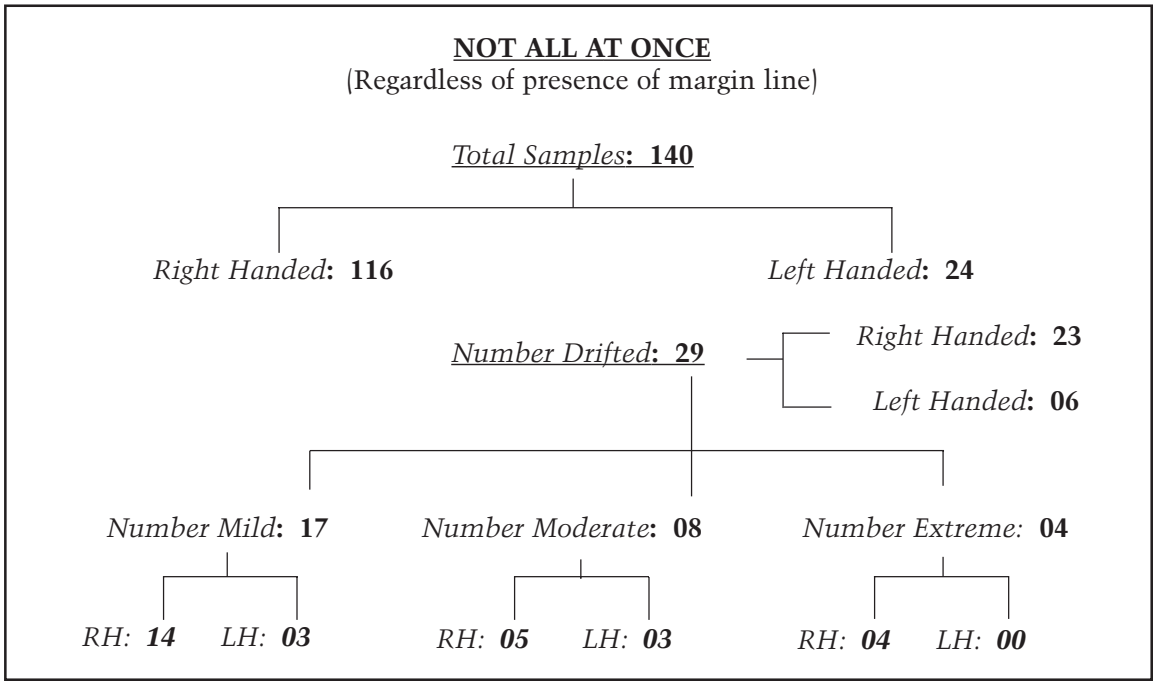
Figure 7. Extreme margin drift (1:1)

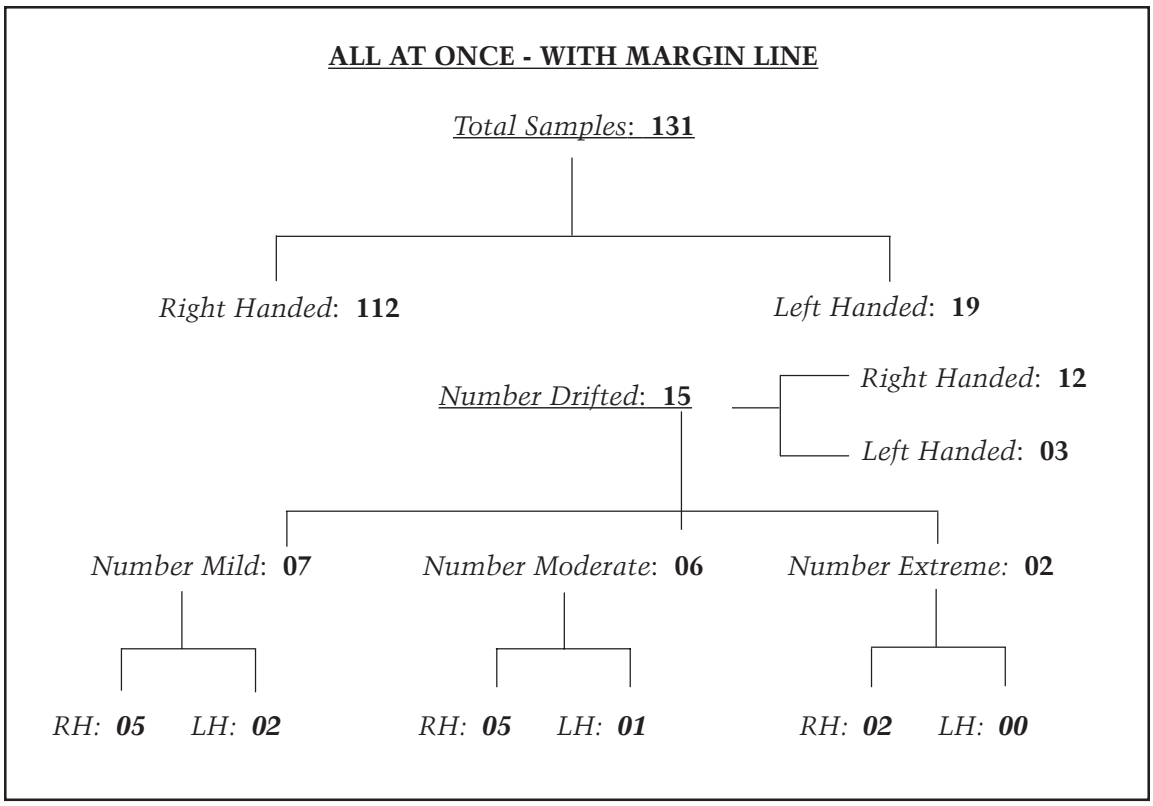
Each series of signatures collected were analyzed and determined to 1) display margin drift or not and, 2) if margin drift was present, to what degree (Extreme, Mild, Moderate).

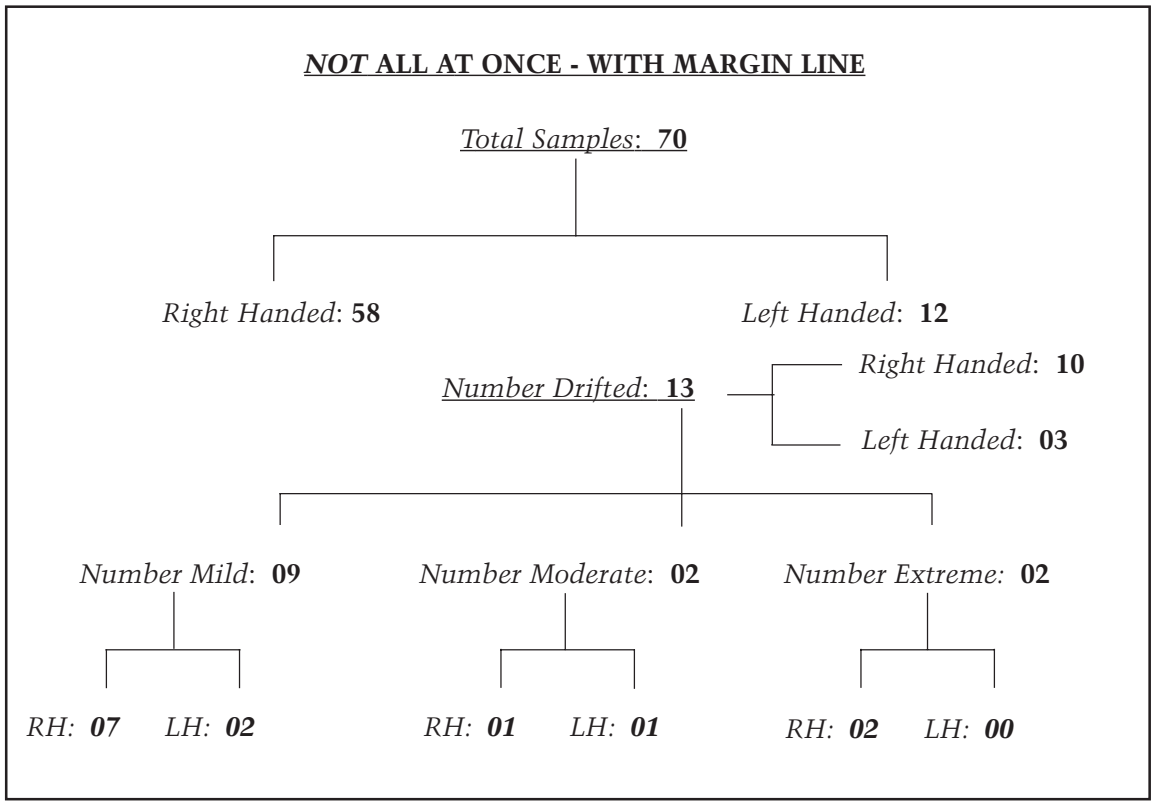
The signature sheets that were signed during one sitting were placed in a category named "ALL AT ONCE" and those sheets that were completed over a period of time were placed in another category named "NOT ALL AT ONCE." Also, each of these two preceding categories were further subdivided into two groups: "ALL AT ONCE-WITH MARGIN LINE" and "NOT ALL AT ONCE-NO MARGIN LINE." The entire set of 402 sheets were reviewed and placed into a corresponding group as follows (Appendix A):

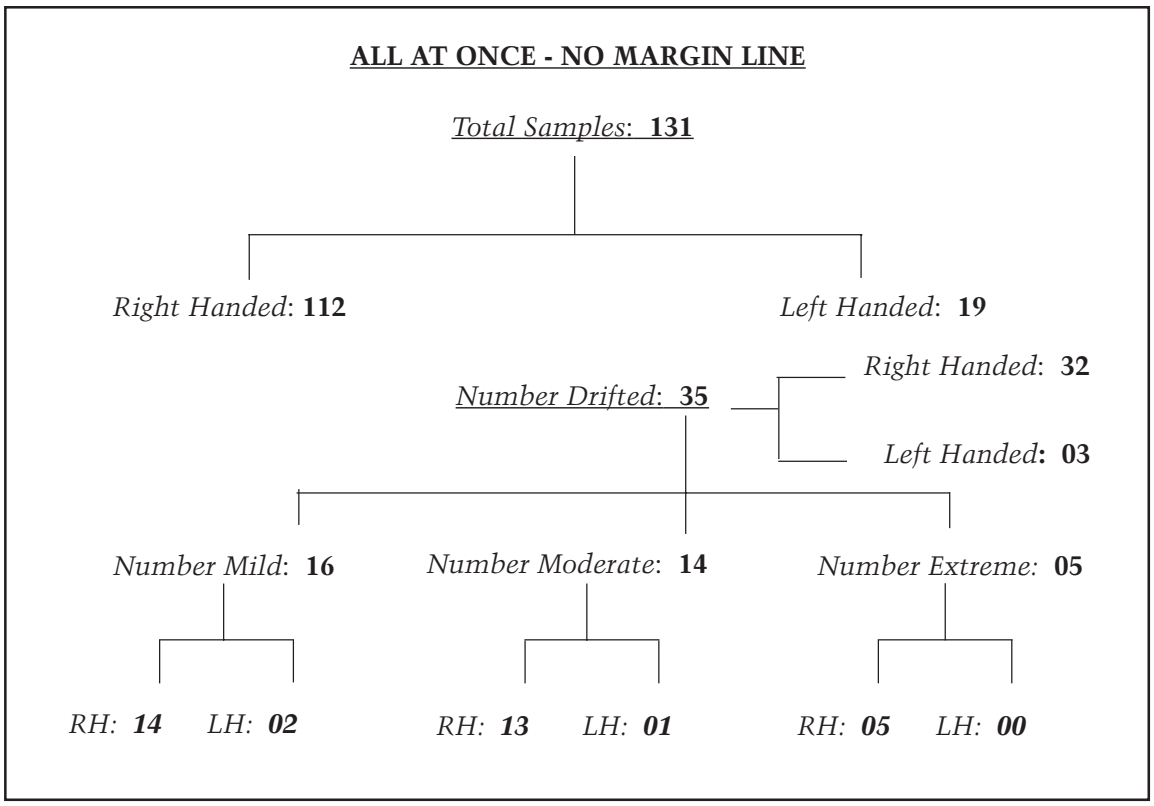
Appendix A. Signature Sheets by Category

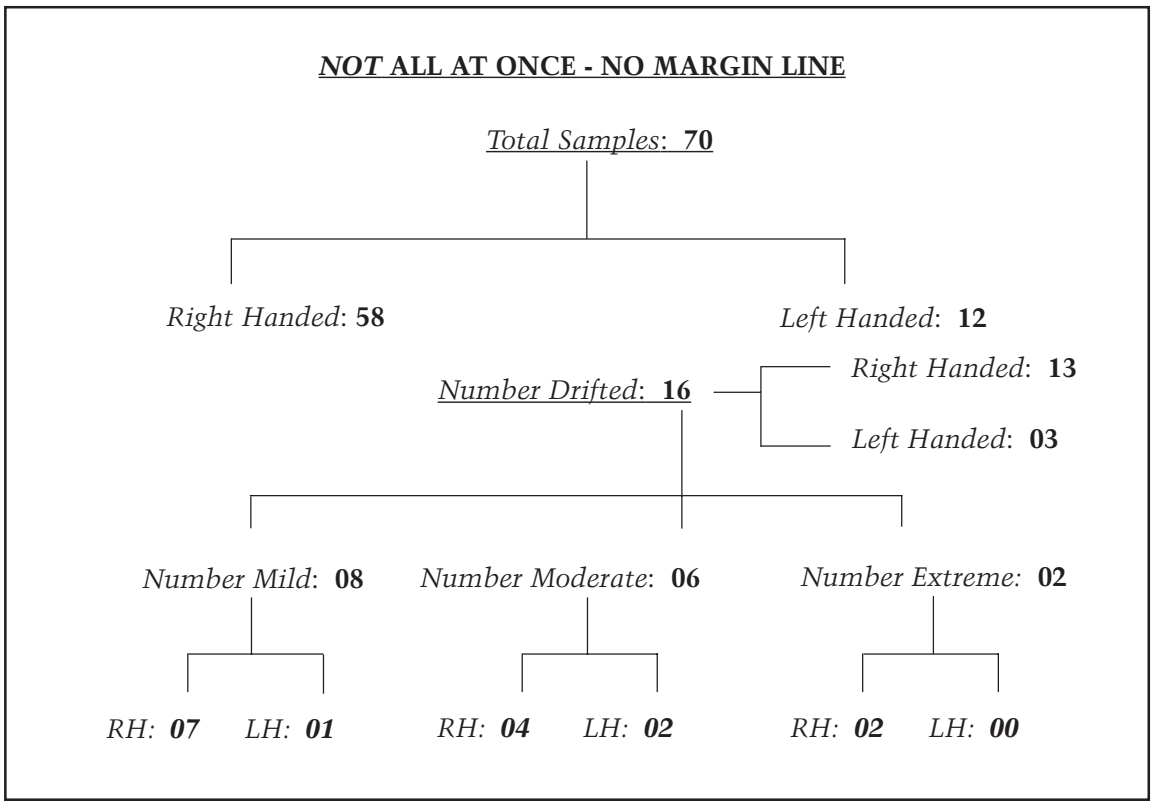





ALL AT ONCE - WITH MARGIN LINE
Total Samples: 131
Right Handed: 112
Left Handed: 19
Number Drifted: 15
Right Handed: 12
Left Handed: 03
Number Mild: 07
Number Moderate: 06
Number Extreme: 02
RH: 05 LH: 02
RH: 05 LH: 01
RH: 02 LH: 00


NOT ALL AT ONCE - WITH MARGIN LINE
Total Samples: 70
Right Handed: 58
Left Handed: 12
Number Drifted: 13
Right Handed: 10
Left Handed: 03
Number Mild: 09
Number Moderate: 02
Number Extreme: 02
RH: 07 LH: 02
RH: 01 LH: 01
RH: 02 LH: 00


ALL AT ONCE - NO MARGIN LINE
Total Samples: 131
Right Handed: 112
Left Handed: 19
Number Drifted: 35
Right Handed: 32
Left Handed: 03
Number Mild: 16
Number Moderate: 14
Number Extreme: 05
RH: 14
LH: 02
RH: 13
LH: 01
RH: 05
LH: 00


NOT ALL AT ONCE - NO MARGIN LINE
Total Samples: 70
Right Handed: 58
Left Handed: 12
Number Drifted: 16
Right Handed: 13
Left Handed: 03
Number Mild: 08
Number Moderate: 06
Number Extreme: 02
RH: 07
LH: 01
RH: 04
LH: 02
RH: 02
LH: 00

"Test Type A" and "Test Type B"

To determine the significance of the raw data, two tests were employed. The first test performed was the normal approximation for testing for a difference between proportions from two populations. For convenience, this will be called "Test Type A" (Appendix B). The second test was the Chi Square test for independence, which will be called "Test Type B." Each of the two tests will be considered separately.

"Test Type A"

This test, which is a test of a hypothesis, was performed five (5) times corresponding to the variations of ALL AT ONCE and NOT ALL AT ONCE populations. The basic question that this test addresses is, **"Are the proportions of drifters from these two populations essentially the same? Or, is there sufficient evidence to conclude that there is a difference between the proportions of drifters, based on whether the signatures were made all at once, or not all at once?"** Since each test is based upon variations of the general hypothesis, this question needs to be slightly altered for each of the five "Type A" tests.

For all of the "Type A" tests, the following variables were used:

Both types of tests will contain the following three symbols:

H_0: This is the "null hypothesis." It states what is being tested. In this case, the null hypothesis is there is no relationship in the proportion of drifters based upon whether they signed their names all at once or not all at once.

H_1: This is the "alternative hypothesis" which is the complement of the null hypothesis. This is the theory that generally represents that which we will accept only when sufficient evidence exists to establish its truth.

α: The level of significance of the test. For each test here, α was chosen to be .05. It means that there is a 5% chance of rejecting the null hypothesis when, in fact, it is true.

n_1: the sample size (number of subjects) from population 1 (ALL AT ONCE)

n_2: the sample size from population 2 (NOT ALL AT ONCE)

X_1: the number of drifters in sample 1

X_2: the number of drifters in sample 2

P_{S1}: the sample proportion from population 1

P_{S2}: the sample proportion from population 2

$\bar{p}$: the pooled estimate of the population proportion

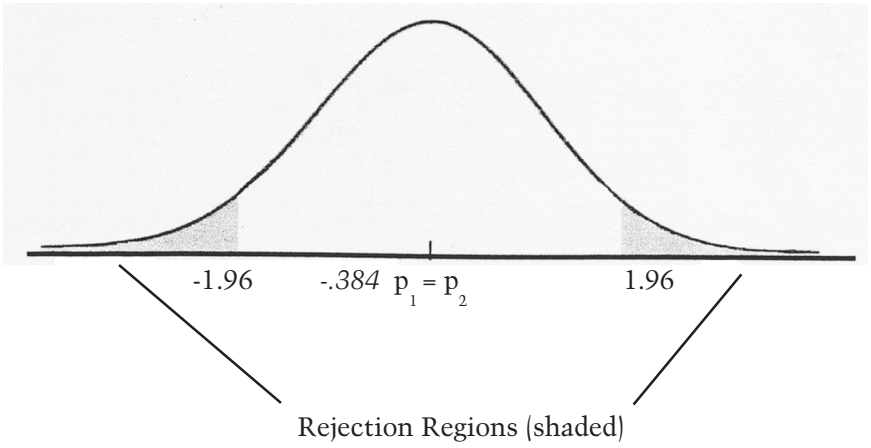
z: the test statistic (based on a normal distribution)

Appendix B. "Test Type A"

TEST #1- TYPE A

ALL AT ONCE (population 1)	NOT ALL AT ONCE (population 2)
$n_1 = 262$	$n_2 = 140$
$X_1 = 50$	$X_2 = 29$
$P_{S1} = \frac{50}{262} = .191$	$P_{S2} = \frac{29}{140} = .207$
$H_0 : p_1 = p_2$	$\alpha = .05$
$H_1 : p_1 \neq p_2$	$\bar{p} = .197$

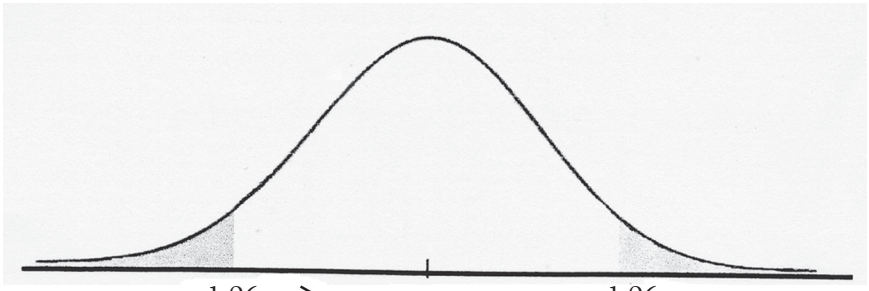
$$z = \frac{P_{S1} - P_{S2}}{\sqrt{\bar{p}\,(1-\bar{p})\,(\frac{1}{n_1} + \frac{1}{n_2})}} = -.384$$



Conclusion: Since -1.96<-.384<1.96 (the test statistic (z) does not fall within the rejection region), there is a failure to reject the null hypothesis. The sample data does not provide sufficient evidence to reject the null hypothesis (H_0) at the 5% level of significance. **There is no evidence of a difference in the proportions of signers who drifted, based upon whether they signed their names all at once or not all at once.**

TEST #2- TYPE A

ALL AT ONCE WITH MARGIN LINE (population 1)	NOT ALL AT ONCE WITH MARGIN LINE (population 2)
$n_1 = 131$	$n_2 = 70$
$X_1 = 15$	$X_2 = 13$
$P_{S1} = \frac{15}{131} = .115$	$P_{S2} = \frac{13}{70} = .186$
$H_0 : p_1 = p_2$	$\bar{p} = .139$
$H_1 : p_1 \neq p_2$	$\alpha = .05$



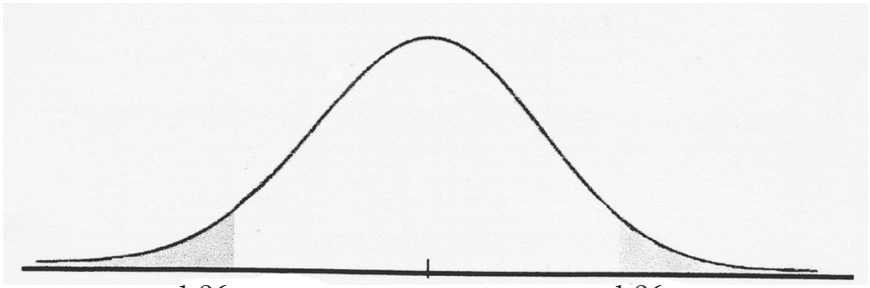
$$z = \frac{P_{S1} - P_{S2}}{\sqrt{\bar{p}\,(1-\bar{p}\,)\,(\frac{1}{n_1} + \frac{1}{n_2})}} = -1.39$$

Conclusion: Since -1.96<-1.39<1.96 (the test statistic (z) does not fall within the rejection region), there is a failure to reject the null hypothesis. The sample data does not provide

sufficient evidence to reject the null hypothesis (H_0) at the 5% level of significance. **There is no evidence of a difference in the proportions of signers who drifted, based upon whether they signed their names all at once on paper with a margin line or not all at once on paper with a margin line.**

TEST #3 - TYPE A

ALL AT ONCE — NO MARGIN LINE (population 1)	NOT ALL AT ONCE — NO MARGIN LINE (population 2)
$n_1 = 131$	$n_2 = 70$
$X_1 = 35$	$X_2 = 16$
$P_{S1} = \frac{35}{131} = .267$	$P_{S2} = \frac{16}{70} = .229$
$H_0 : p_1 = p_2$	$\bar{p} = .254$
$H_1 : p_1 \neq p_2$	$\alpha = .05$



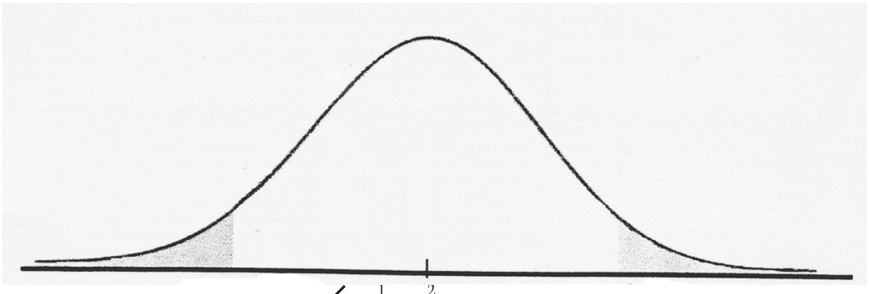
$$z = \frac{P_{S1} - P_{S2}}{\sqrt{\bar{p}\,(1-\bar{p})\,(\frac{1}{n_1} + \frac{1}{n_2})}} = .590$$

Conclusion: Since -1.96<.590<1.96 (the test statistic (z) does not fall within the rejection region), there is a failure to reject the null hypothesis. The sample data does not provide sufficient evidence to reject the null hypothesis (H_0) at the 5% level of significance.

There is no evidence of a difference in the proportions of signers who drifted, based upon whether they signed their names all at once on paper with no margin line or not all at once on paper with no margin line.

TEST #4 - TYPE A

ALL AT ONCE — RIGHT HANDED	NOT ALL AT ONCE — RIGHT HANDED
$n_1 = 224$	$n_2 = 116$
$X_1 = 44$	$X_2 = 23$
$P_{S1} = \frac{44}{224} = .196$	$P_{S2} = \frac{23}{116} = .198$
$H_0 : p_1 = p_2$	$\bar{p} = .197$
$H_1 : p_1 \neq p_2$	$\alpha = .05$



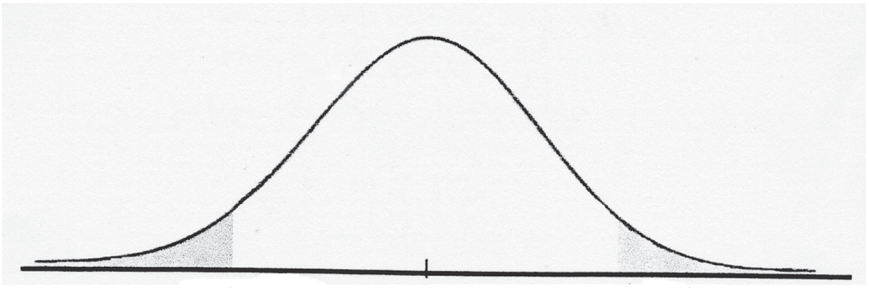
$$z = \frac{P_{S1} - P_{S2}}{\sqrt{\bar{p}(1-\bar{p})\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} = -.044$$

Conclusion: Since -1.96<-.044<1.96 (the test statistic (z) does not fall within the rejection region), there is a failure to reject the null hypothesis. The sample data does not provide sufficient evidence to reject the null hypothesis (H_0) at the 5% level of significance.

There is no evidence of a difference in the proportions of right-handed signers who drifted, based upon whether they signed their names all at once or not all at once.

TEST #5 - TYPE A

ALL AT ONCE — LEFT HANDED	NOT ALL AT ONCE — LEFT HANDED
$n_1 = 38$	$n_2 = 24$
$X_1 = 6$	$X_2 = 6$
$P_{S1} = \frac{6}{38} = .158$	$P_{S2} = \frac{6}{24} = .250$
$H_0 : p_1 = p_2$	$\bar{p} = .194$
$H_1 : p_1 \neq p_2$	$\alpha = .05$



$$z = \frac{P_{S1} - P_{S2}}{\sqrt{\bar{p}\,(1-\bar{p})\,(\frac{1}{n_1} + \frac{1}{n_2})}} = -.892$$

Conclusion: Since -1.96<-.044<1.96 (the test statistic (z) does not fall within the rejection region), there is a failure to reject the null hypothesis. The sample data does not provide sufficient evidence to reject the null hypothesis (H_0) at the 5% level of significance.

There is no evidence of a difference in the proportions of left-handed signers who drifted, based upon whether they signed their names all at once or not all at once.

"Test Type B"

"Test Type B," the Chi square test for independence, was performed only once. This test addresses the question, "Is there a relationship between the way the signatures were collected (all at once vs. not all at once) and drifting?"

For the "Test Type B," the following variables are used:

R: the number of rows in the contingency table

C: the number of columns in the contingency table

f_O: the observed frequency in each cell of the table (this value represents the number that would go in that cell if, in fact, the two populations were the same)

f_1: the theoretical frequency in each cell of the table

χ^2: the test statistic ("chi-square")

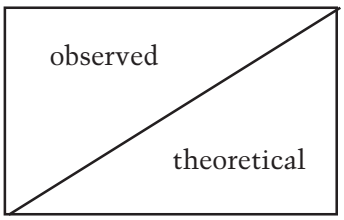
H_0: There is independence (no relation ship) between times of signatures and drifting

H_1: There is a relationship between times of signatures and drifting

α = .05

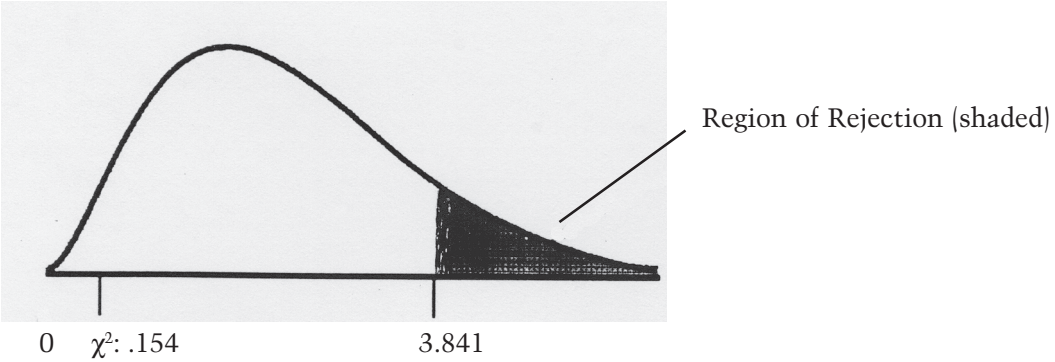
Appendix C. "Test Type B" Chi Square Test for Independence

	Drifted	Did Not Drift	TOTALS
All at once	50 / 51.49	212 / 210.51	262
Not all at once	29 / 27.51	111 / 112.49	140
	79	323	402



degrees of freedom: (R - 1)(C - 1) = 1

Cell #	f_0	f_1	$f_0 - f_1$	$(f_0 - f_1)^2$	$\frac{(f_0 - f_1)^2}{f_1}$
1	50	51.49	-1.49	2.2201	.0431
2	212	210.51	1.49	2.2201	.0105
3	29	27.51	1.49	2.2201	.0807
4	111	112.49	-1.49	2.2201	.0197
					χ^2 = sum = .154



Conclusion: Since .154<3.841, there is a failure to reject the null hypothesis. The test statistic, (χ^2=.154), does not lie within the region of rejection.

There is no evidence of a difference between those who signed all at once and those who did not sign all at once in the tendency of signers to drift.

Discussion

The preceding statistical data enlightens us greatly in the significance of margin drift. Margin drift was present in both the writers who signed their name on one occasion and the writers who signed their name on several different occasions. There was no need to further examine the subdivisions within margin drift (Mild, Moderate and Extreme), because the data showed that there was no correlation between margin drift and writers who sign at one time or on different occasions. In fact, no test was even close to establishing such a relationship.

When margin drift is present in extended writing, a Forensic Document Examiner (FDE) must be careful not to use this drifting phenomenon as a significant factor in reaching a conclusion as to whether the writing was written at one time or on different occasions. Illustrated by this study, margin drift is not indicative of writers who signed their names repeatedly, in one sitting, therefore, margin drift is not a particular characteristic of multiple signatures composed all at once. Simply stated, FDEs cannot use margin drift as a factor in determining if signatures were written at one time or over a period of time.

Acknowledgements

Appreciation is extended to Mary V. Prial, Statistician, who assisted us in interpreting the data in this study. Ms. Prial was able to test our data in six different tests in order to validate our hypothesis.