

Regional and National Variation in Arabic Handwriting

By

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**A thesis submitted in partial fulfilment for the requirements for
the degree of Doctor of Philosophy at the University of Central
Lancashire**

April 2013

Declaration

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the University or other academic or professional institution.

I declare that no material contained in the thesis has been used in any other submission for academic award and is solely my own work.

Ahmed A. Al hadhrami

Abstract

It has been established in a number of research publications that a careful study of general handwriting features based on class characteristics could indicate either the place or the country where the writer was first taught to write. Using these studies as the basis, this research was carried out explicitly to understand the characteristics of Arabic handwriting. The aim of this study was to determine the presence of any particular features or characteristics that may be common to individuals of a given region or nationality. This was done by obtaining samples of handwriting collected from individuals of four countries including; Jordan, Morocco, Oman and Tunisia, where Jordan and Oman are considered to be Eastern Arab world and Morocco and Tunisia in the Western Arab world.

An attempt was made to establish whether it was possible to determine either the region or nationality of the writer of an Arabic passage of text, based on the formation and the style of the handwriting using specific Arabic characters. Different steps were taken towards the identification of the class characteristics of Arabic handwriting in this study starting with the collection of 600 handwriting samples from the participants in four Arabic countries employing; 150 handwriting samples from each. Ten different characters and one word were selected for examination, with more than one form of each character in different positions being identified and the handwriting samples classified accordingly. In total, 221 class characteristics were identified from the samples based on different criteria including the shape, number of strokes, pen movement and starting point.

Tests of association using chi-squared on individual characters showed that the p-value is less than 0.001 in every case. Correspondence analysis was used to produce a plot of relative similarities where the different countries appear as discernible, but overlapping groups. ANOSIM showed these groups to be statistically different ($R = 0.321$ $p = 0.0002$, 1000 permutations). Tree analysis was used to create a classification system and blind tests were conducted to test the accuracy of the classification system. On the basis of the statistics used, significant differences were found in character forms used by the

individuals from the four Arabic countries, suggesting that either region or nationality of the writer may potentially be predicted with a useful degree of accuracy. Though the samples were obtained from only four countries out of a total of 22 Arab countries and only ten characters and one word out of 28 characters were chosen in this study, the results obtained are valuable and useful, particularly to Forensic Document Examiners (FDEs). In turn this could be implemented in practice in a situation where a questioned document containing Arabic text is presented and the suspected author could have come from one of the four considered countries.

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Acknowledgements

This study of almost four years would not have been possible without the constant and untiring support of several individuals. I sincerely thank each one of them for their contribution. First and foremost, I am grateful to the University of Central Lancashire (UCLan) for giving me this opportunity to conduct my study. Very importantly, I acknowledge the support of Dr. Allison Jones, Director of Studies and the Dean of the School of Forensic and Investigative Sciences at UCLan, my supervisors, Dr. Colin Moffatt, a statistics expert and Dr. Mike Allen, a handwriting expert, without whose regular and timely assistance the study could not have been completed in time and in a professional manner. At each phase of the study, their support, guidance and supervision have played an important role in the progress of the study. I thank Prof. Mike Holmes, Head of the Graduate Research School at UCLan and Prof. Jaipaul Singh, Research Degree Tutor, for their support in the initial stages of the study. A word of thanks to Clare Altham, Senior Administrative Officer at UCLan for taking care of all my registration and logistics needs. I acknowledge the support provided to me by in-country supervisor A. R. Srinivasan who relentlessly offered his valuable time and help throughout this study. My deepest appreciations go to Abdullah A. Al Hajri who has rendered his assistance voluntarily over the years, Mohammed R. Al Abdulsalam for his effort and support and Ali Al Durmaky who so generously obtained the handwriting samples from Jordan. I wish to thank my organisation of work, the Royal Oman Police, for providing me the ethical approval and allowing me to take up this study. Over six hundred participants who provided their handwriting samples for the study have made an immense contribution to this research for which I am highly indebted to each one of them. Last but not

the least, my mother, my wife and children have undergone several sacrifices in supporting me to take up this study and I am ever thankful to them for having been so encouraging, considerate and understanding.

Abbreviations

- A. ANOSIM - Analysis of Similarity
- B. CA - Correspondence Analysis
- C. DCD - Developmental Coordination Disorder
- D. FDE - Forensic Document Examiner
- E. GS - Glottal Stop
- F. MSA - Modern Standard Arabic

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1 INTRODUCTION

Handwritten evidence has long been considered a very important and effective piece of information for forensic investigation purposes due to the widely prevalent need for identifying the source of different forms of related crimes, involving contracts, insurance policies, kidnapping, murder and international terrorist threats. In forensic writer identification, available pieces of handwriting are scrutinised to identify a writer of the questioned document. This is traditionally done by the Forensic Document Examiners (FDEs) using various methods.

In this study of Arabic handwriting amongst nationalities of four countries, Jordan, Morocco, Oman and Tunisia, effort is made to determine whether substantial and statistically significant variation exists among writers from Arabic countries. It also aims to establish whether any relationship exists between handwritten Arabic texts and either the writer's region or nationality using class characteristics of Arabic handwriting. These together are expected provide valuable assistance to the FDE in identifying the writer's origin.

This chapter is a general introduction to handwriting, its various characteristics, influences of copybook styles and teaching methods of handwriting, handwriting variation, factors that influence handwriting. A research question along with the aim of the study is proposed. In the subsequent chapter, a brief history of Arabic language and its characteristics is provided followed by a chapter on the materials and methods used in the study. The next chapter presents the results of the study and the last chapter discusses the whole study, its limitations and possible future studies.

1.2 HANDWRITING CHARACTERISTICS

Handwriting, considered as an acquired skill, is a complex process which depends on the interaction between the muscles of the arm, wrist, fingers and hand, with visual feedback all controlled by the brain. Levinson (2001) stated that handwriting is a complicated operation that takes the average person many years to learn. Only over considerable time can one develop the coordination of arm to hand to finger movements needed for what can be loosely coined as the handwriting of a literate person. Vos, *et al* (2000) described handwriting as the formation of letters, characters or symbols using a writing implement, according to a recognisable pattern which is designed to communicate to another person.

Handwriting typically is a compound, cognitive and motor skill. The writer has to deal with the often complex components of a language such as specific sets of phonemes and set of letters used in the alphabet (Van Galen, 1991). Handwriting is a skill that requires control over fine movements of the hand and fingers and develops through a long and complex process, to which schooling and the child's motor, perceptual, and cognitive developments contribute (Chartrel and Vinter, 2008). The development of writing is complex because it is, in part, culture dependent and moreover, cultures differ with locales and undergo constant change. The evidence of this dependence is manifest in either class, system, or national characteristics (Huber and Headrick, 1999).

Handwriting is a multi-joint task that requires fine motor control in order to translate an abstract motor memory into a series of muscular and limb movements with the ultimate goal of producing an endpoint trajectory that results in a relatively invariant and recognisable pattern (Longstaff and Heath, 2003). The precise ordering and timing of the movements determines the

structure of the pattern that is recorded by the pen or pencil (Huber and Headrick, 1999).

Handwriting involves different processing levels. From the intention of writing to the actual movement execution, there may be different modules in the brain that allow for semantic activation, syntax construction, spelling recovery, allograph selection, size control and muscular adjustment (Van Galen, 1991) and these modules must communicate with one another (Kandel, *et al.*, 2006). Two types of movements are involved in handwriting including; those responsible for the production of the shapes of the letters and those enabling the spatial layout of the characters on the page, corresponding to the morphokinetic and topokinetic components, respectively (Chartrel and Vinter, 2008). The handwriting of some people's handwriting may have certain styles and characteristics in common, acquired when these people learned to write by copying letters and words. However, writers tend to develop individual characteristics with age. Also, as a person ages, the handwriting will show additional changes (Naider, *et al.*, 2007). As an individual act, the handwriting characterises its writer by the reproduction of details and unconscious practices. The reason is very simple; the handwriting habit of one person is formed by a long period of practice in one's childhood which is therefore difficult to change when he/she grows up (He, *et al.*, 2008).

The handwriting features or characteristics consist of two groups including; class and individual. Both features are considered by Forensic Document Examiners as important tools for either handwriting classification or identification purposes. Class characteristics may be conspicuous for the layman and could be used to put handwriting samples in different groups, while

individual characteristics are generally individualistic and are not easily understood by a layman, but for the FDE they are valuable for handwriting identification. In other words, the class characteristics occur when a group of writers share a common writing style. This could be because they have similar levels of education or are part of the same family. The individual characteristics are those which are particular to a single person who has executed his writing in a specific or unique fashion. The study of handwriting features, as practised by experts in the identification and comparison of handwriting specimens and documents, is a complex scientific approach that may uncover similarities in handwriting specimens that are not evident to the untrained eye (Bradley, 1986).

It is essential for the handwriting expert to give a proper analysis and moreover, to consider carefully both characteristics in order to reach a correct conclusion. Failure to do so may lead to a wrong result and consequently will mislead the court of law.

1.2.1 Class characteristics

Class characteristics are a group of features found in many types of products either made by humans or machine. These features are predictable as they are deliberate and introduced during manufacture. Examples are the shape, design or size of any object. These characteristics are shared between individuals in a particular group or family, and could be used to associate any member to the related family or group.

There are a number of definitions of class characteristics in regards to handwriting. Many of the writing habits that are developed as young people are carried over into our adult style of writing. These are called class characteristics.

Not all characteristics encountered in document examination are peculiar to a single person but one that is common to a group may be described as a class characteristic (Hilton, 1983). Some class characteristics are considerably more common in some countries than others (Berthold, and Wooton, 1998).

Class characteristics, as the name implies, are those common to a number of writers, and may result from such influences as the writing system studied, family associations, trade, training, and education (Hilton, 1983). Either class or style characteristics, which, Document Examiners refer to as writing characteristics are those attributable to a model system (Vos *et al.*, 2000). As a result of the similar class characteristics possessed by a number of writers, analysis of a set of handwriting samples start with this type of characteristic (Saxena and Singh, 1992).

Class characteristics are those aspects, elements or qualities of writing that place a person within a group of writers or give a written communication a group identity (Huber and Headrick 1999). Saferstein (1995) defined class characteristics as properties of evidence that can only be associated with a group and never with a single source. These types of characteristics are found in the handwriting of groups of people and are not peculiar to a single individual. Such characteristics are regarded as one of the main elements of handwriting structure. Since they have a common origin, they are frequently found in the writing of different people. These are characteristics of a style rather than of the writing method of individuals and are therefore sometimes called style characteristics (Ellen, 1997). It is believed that the careful study of these general handwriting features could indicate the place or the country where the writer was first taught to write (Cheng, *et al.*, 2005). Such characteristics are a

valuable tool in forensic examinations, as the Forensic Document Examiner could rely on them to at least narrow the search and so save time and resources (Kerr, *et al.*, 1992).

There are different areas in forensic science that utilise class characteristics as one of the stages of their examinations. Examples of these areas include tool marks, firearms, footwear, tyre prints, handwriting, fibers, hair and many other types of physical evidence that could be found at a crime scene. If a Forensic Examiner, for instance, wants to examine fibers, he will compare first the class characteristics, which include colour, length of the fiber, diameter and other microscopic features. Proper assessment of such features will be of evidential value, and understanding such evidence is very important in building a case. The same can be said of handwriting, which includes both class and individual characteristics.

Levinson (2001) reported that class characteristics can range from features found in large groups of writers to those features that are found much less frequently. In addition, this kind of evidence is of use for the purpose of handwriting classification and it is a useful means to identify a family or particular group, without limiting these characteristics to a small group or a small number of individuals. However, the handwriting expert cannot depend upon them on their own to draw a conclusion, and therefore, as a consequence, this type of physical evidence cannot be linked to a particular individual. In other words, as Finch (1992) stated that it is generally agreed that the similarities or differences in letter forms or with class characteristics alone do not provide the basis for identification or elimination. But, when this sort of evidence is combined with other types of police investigative evidence such as confessions,

hearsay, observational evidence or eyewitness testimony it will be of value for the court in order to reach a correct judgment.

Class characteristics are the most obvious features of handwriting that are acquired by children or others during the course of learning to write. These characteristics are of little value for identifying the individual of a handwritten text. This is of some importance in a country which has immigrants from other countries (Harrison, 1958). Schuetzner (1999) mentioned that the class characteristics of hand printing (hand lettering), which is disconnected letters, are used in the identification and elimination of a writer when a manuscript is in question. Class characteristics are various; including the shape of the character, position and number of dotting, pen lift, the size of writing, slope, alignments and so on. Furthermore, the writing direction is considered to be a class characteristic, as some writers deviate from the normal writing direction. Each class characteristic is variable within a population of writers. Most of these characteristics are very common while some are written by only a small number of writers. As such, class characteristics analysis can be applied to classify the handwriting into different groups; by doing that, an indication of the frequency of occurrence of some characteristics can be measured. Furthermore, a system can be created to search for a particular feature instead of checking each single sample in its writing.

The author has come across various studies that have been carried out on handwriting class characteristics using different methodologies, parameters and sample sizes. The focus of these studies was on the influence of the mother languages and related copybook styles in the English handwriting of some ethnic groups of different countries. These studies concentrated on the

identification of the common class characteristics in the handwriting of those people and hence, the possibility of identifying the geographical origin in which the writer was taught to write. Valuable information was obtained from such studies and as it could assist Forensic Document Examiners in determining the writer's region or country in which they learned to write (Katsaridou, 2009).

One of these studies was carried out by Turnbull *et al.* (2010) investigating the class characteristics of Polish people writing in English and to specifically identify those characteristics that separate Polish handwriting from English handwriting. In the study forty Polish and forty English handwriting samples were systematically examined using different statistical methods. Thirty one features were identified and twenty one of these were found to be occurring significantly more in Polish compared to English handwriting.

The English handwriting of three main racial groups in Singapore (Chinese, Malay and Indian) was also examined by Cheng *et al.* in 2005. The study examined fifty samples from each group to investigate the influence of the other languages learned by those groups in their English handwriting. Ten highest frequencies occurring class characteristics were selected and six common class characteristics were identified by using chi-squared analysis. These common features were found to be statistically significant.

In her research, regarding class characteristics of the English handwriting of Greek people, Katsaridou (2009) attempted to establish whether unusual class characteristics are more common or unique in the handwriting of Greek individuals compared to the handwriting of English people and investigated whether the handwriting of Greek group writing in English present similarities with the letters of the Greek alphabet. In this research 50

handwriting samples from Greek and 50 samples from English people were examined by using three different statistical methods. Forty class characteristics were identified in the handwriting of Greek people writing in English, five of which resembled letters of the Greek alphabet. Muehlberger (1989) has examined the handwriting of Hispanics who were born in Latin America and were living in the USA. Common class characteristics of Hispanic people were found in their handwriting.

As mentioned by Turnbull (2010), Simner and Smits-Englesman (2000) have found that Canadians, who had been taught to write in Canada, were more likely to have features in their writing that reflect letter shapes found in Canadian copybook design and similarly, Dutch copybook design was more likely to be found in the writings of Dutch students.

1.2.2 Individual characteristics

Over a period of time, as the learner becomes independent and departs from the core features of the writing system, he or she starts to develop peculiarities in handwriting and acquires certain personal writing characteristics which are considered as backbone of identification (Hilton, 1983). Once the writer has acquired writing skill with the passage of time, it is difficult to change writing characteristics and create a new form of letters. However, rapid change will occur in the writing characteristics as the individual builds further writing skills.

The unusual occurrence of handwriting features that are specific to an individual's writing are called individual characteristics. Writer individuality rests on the hypothesis that each individual has consistent handwriting that is distinct from the handwriting of another individual (Srihari *et al.*, 2002). Hilton (1983)

defined individual characteristics as those that are highly personal or peculiar and are unlikely to occur in other instances.

In their article, Vos *et al* (2000) mentioned that from the moment people start learning to write, they introduce deviations from the model writing system taught. The extent of these deviations increases as the writing style becomes more personalised, resulting in a style which is the product of many factors including the model system, artistic skill, perceptual ability, muscular control, nature of employment, frequency of writing and exposure to the writing of others. This leads to an individual writing style, the development of which occurs throughout the childhood and adolescent years and often beyond. An understanding of movement control factors involved in the production of handwriting is therefore likely to be relevant to within-writer consistency (Wing and Nimmo-Smith, 1987). Morris (2000) reported that these characteristics are peculiar to the writing of a particular individual and constitute his or her writing habits. These features are responsible for creating the handwriting characteristics of the writer and are used to distinguish between writings, sometimes called personal characteristics.

During handwriting examination, certain points must be accounted for in order to establish that two writings are from the same source (Baxendale and Renshaw, 1979). Huber and Headrick (1999) suggest that the particular writer may be identified from writing attributes such as form, slant, direction and proportion. Li, *et al*. (2005) reported that the fundamental differences in either form or movement are the means of distinguishing numerals written by different individuals. Experience has shown that a few strong and unique individual features could be sufficient to rely on and reach a conclusion of either a positive

or negative result. From the examined cases that involve Arabic handwriting, two or more repeated and consistent individual characteristics such as the shape and position of dots could be sufficient, at times, to draw a conclusion (Othman, 1966).

Differentiation between class and individual characteristics by the FDE during the stage of handwriting examination is very important. The reason being that there are some features found in the handwriting of some people who do not write very often in their life and these characteristics are a result of the style or the writing system taught but not of the way they have developed to write.

Handwriting has long been considered by Forensic Document Examiners to be unique to a person (Pervouchine and Leedham, 2007), and distinctive individual behaviour (Eldridge, *et al.*, 1985; Al-dmour and Abu Zitar, 2007). The patterns of handwriting which distinguish the script of one person from that of another have been attributed to a variety of influences including the writer's perceptual abilities, physiology, musculoskeletal system, nervous system, intellectual development, emotions, and motivations (Bradley, 1986), as well as education and occupation (Kerr, *et al.*, 1992). This combination of features is reflected in an individual handwriting pattern which may be impossible to duplicate in its entirety. Eldridge, *et al* (1984) have computed the likelihood that two writings by different authors would be identical in only 12 characteristics of the 500 or more found in a typical page of handwriting.

On the basis of letter design alone, there are a number of individual characteristics and unlimited distinguishable features that are of use for either handwriting classification or identification purposes. However, the Forensic Document Examiner cannot rely on only one feature such as character form of

a single letter in order to identify a particular writer, even if it is very unusual. If a sufficient amount of writing is available, it is the combination of distinctive and common characteristics that serve to identify the handwriting of a particular individual.

1.3 THE INFLUENCE OF COPYBOOK STYLE AND TEACHING METHODS ON HANDWRITING

The copybook style or the writing system is defined as the writing model that is taught to children when learning to write. Hilton (1984) defined the copybook style as “The design of the letters that is fundamental to a writing system”. This term was derived from the old methods of teaching handwriting from a copybook containing engraved script printed on each page for the student to imitate.

Copybook style is always printed in a particular way and used for the purpose of teaching both illiterates and children when learning to write. In addition, it could be used by anyone who wants to learn how to write. It contains the characters, numerals and simple words which can be easily understood (Nassar, unpublished). The writing system requires instruction which should be followed by any individual who wants to acquire writing ability. There are two ways by which a person could learn handwriting, one of which is the copybook style, or what is called the writing system, and the other method is following the instructions given by a teacher to learners or what is called the teaching method.

A system of writing includes not only the design of the letter forms, but also the method of instructions on the formation of these designs, in other words the path that the pen makes to write the written character. The influence

of the system will result in handwriting characteristics prevalent among writers who studied that particular system (Muehlberger, 1989). Since many people learn to write from a copybook style and according to the instructions given within that book, the shape of the letters are constructed and as a sequence, the general appearance of the class characteristics of their handwriting would be obvious and common amongst those set of people.

The lack of a standard copybook style in a specific community or country clearly will result in the absence of literature and any other written heritage, and as a result, the new generation of people will lose a crucial role. Writing overcomes such problems and allows communication across space and through time. If copybook patterns for any particular country or region adhered to a certain range consistency, and also were sufficiently different from those of other countries, a national origin determination would be practicable (Conway, 1959). However, differences in styles from one country to the next are sometimes minimal but sometimes systems used within a particular country vary considerably (Stangohr, 1971). Copybook styles are subject to periodic review and change and it is not likely to have one style for a long time and throughout a region, for example, the Arabic world. In addition, the copybook style not only differs between countries but also changes over a period of time within the same country. Also, Ellen (1997) mentioned that, even within a single country at a particular time, there are other variations in style caused by different teaching methods.

The teaching of these styles will obviously influence the writing of those who learn from them (Brown, 1985). The cause of the departure from the writing standard and the modification of the writing methods by the learners

could be accounted for in many ways, including the learners are not able to follow the writing model precisely, to create an independent writing personality, or because of frequency of the writing habit, individual taste, degree of manual dexterity, occupation, environment or for some other unknown reason (Miller, 1972). Whatever the reason, it is clear from observation, that it is not possible for a teacher to produce identical results, like a printing press turning out copies (Ellen, 1997).

In other words, any person who learns to write any given style or system of handwriting will tend to deviate from it and incorporate into their writing their own individuality. The independent handwriting personality begins at the early stage of the learning process. This occurs when the child starts to depart from the copybook standard. However, learners are varied in their acquisition of personal characteristics, as some of them control the pen movement and produce well shaped strokes at the very outset of the process, whereas others acquire this skill over a period of time (Graham and Weintraub, 1996). The time spent in acquiring the writing skill and producing accurate and smooth letters seems to bear little relation to the level of intelligence. It has been observed that most people with drawing skills exhibit good handwriting (Bonoti *et al.*, 2005).

Consequently, the study of copybook style could play a very important part in determining the place in which the writer was taught to write. Moreover, it may be possible to determine whether or not the document was written by someone who is young or old (Harrison, 1985). The other outcome from studying the copybook standard of the document in question is the reduction of the scope of the suspect population, which is regarded as a significant step towards the identification of the writer, leading to time and effort saving

(Manfredi, *et al.*, 2005). Even in the uncommon case in which an individual exhibits different styles of writing, the questioned document examiner may conclude that the writing styles share critical identifying features after applying forensic methods for comparing handwriting characteristics (Osborn, 2010). Forensic Document Examiners should be knowledgeable in regard to the national copybook style(s) and the teaching methods and its associated influence in the handwriting in a given place at relevant time periods. In addition, referring to the copybook style is a useful tool for class characteristics identification particularly in a case of foreign handwriting. The distinctive shape or design of certain characters is regarded as significant by the FDE, when they vary from the copybook style.

1.4 HANDWRITING VARIATION

It is not possible for any person to produce identical writing on any two occasions. The writing will always vary from one time to the next and this is termed "variation" (Hilton, 1993). Huber and Headrick (1999) defined natural variation as imprecision with which the habits of the writer are executed on repeated occasions. This is an ever-present feature of handwriting and as Harrison (1958) stated, variation is not haphazard but instead has several governing factors. Variation in handwriting is attributed to the complicated process of writing and it being a work involving combination of parts of the body including muscle groups in the hand, wrist, arm and shoulder which controlled by the brain and it is not a product of a machine. Thus, variations will always exist. Regardless of the place, date, time, or writing instrument used, variation will occur as a normal feature in the handwriting of any individual. Furthermore, other factors have some influence on this process, such as the state of health of

the writer and physical conditions under which the writing was executed. Similarly, the mental state of the writer may have an effect on his handwriting and may cause a large amount of variation. Slight changes from one time to another are responsible for the presence of variation between handwriting samples (Meulenbroek and Thomassen, 1991).

As variation is normal and expected to be present in handwriting among individuals, different elements, such as, the shape of characters, slope, spacing, alignment and the letter construction play an important role. For example, spacing between words and between letters within word varies greatly within individual style (Alkahtani and Platt, 2010). Huber and Headrick (1999) stated that natural variation in writing has been spoken of as if it was a general attribute that affects all of the aspects of writing in some common fashion and it is in each of the discriminating elements of writing.

In their study relating to the effect of brain cancer on writing, Duncan and Gilbertson (1983) found that individuals suffering from brain cancer in different parts of the brain showed very obvious changes in their writing. They reported variation in several components of the writing. Similarly, different types of blindness and differing degree of loss of vision were seen to have a range of effects on the writing of visually impaired individuals (Morgan and Zilly, 1991).

Variation in the handwriting could occur as results of the writing speed since, correlation between speed and legibility was found by Ziviani *et al.* in 1998 in their study of the writing of 7 – 14 years old school students. The speed and level of care of writing, fatigue and state of intoxication were seen to contribute to the occurrence of variation (Hilton, 1969). Speed and context can also be contributing factors to variation; practiced writers that write quickly often

tend to slur the execution of some letter combinations, especially word endings, and that can greatly affect the letter shapes, perhaps to the point of rendering them unreadable as individual letters (Huber and Headrick, 1999). In addition, significant variation in the handwriting of left and right handed writers was reported by Franks, *et al.* (1985), indicating that the differences between two samples of handwriting could be due to handedness.

Variation is a significant manifestation of genuineness in writing and can be seen in lateral spacing proportion, slope and size of figures and characters. However, this has little effect on the fundamental structure of handwriting characteristics, over a period of about ten years (Kapoor and Sharma, 1985). Variation itself differs in extent amongst people, being slight and only in details with some writers and more pronounced with others. The determination of the consistency of such features, how it varies across individuals and within one individual's writing is essential as it can be used to distinguish between forged and genuine writing (Totty, *et al.*, 1987).

Differences between two writings are not always due to different writers being responsible and may instead be as a result of variation in a single person's handwriting. Moreover, some people are capable of writing in more than one style and they have the ability to write naturally in very different modes. Differences are normally considered significant when two writings are compared and found to be of greater than expected variation (Ellen, 1993). Normal variation and significant differences may be confused unless there is evidence in the writing to help classify them into the appropriate categories. If a reasoned judgment is not possible, the differences are most safely classified as "unexplained" instead of significant and an incorrect opinion is thereby avoided

(Alexander, 1997). In such circumstances, the document examiner must, report that he or she is unable to confirm the authorship of the writing under consideration (Whiting, 1990). Therefore, assigning proper weight to both similarities and differences alike is necessary for the document examiner if he wishes to be accurate (McAlexander, 1997).

It is well known amongst Forensic Document Examiners that the recognition of variation versus significant differences is regarded as an essential part of forming a correct conclusion, as the elimination of the suspect author cannot only be by the mere presence of differences between the questioned and known writing (McAlexander, *et al.*, 1991). As variation is always present in all handwriting components such as style, slope, slant, alignment, spacing and pen lift, it serves to personalise and identify writing (Leung, *et al.*, 1987). Therefore, it is necessary to determine these fundamental elements and habits of writing with an accurate range of variation (Hilton, 1984). The general spacing of numerals and characters will have a considerable range of variation between writers as some individuals will put twice as many letters or figures in a given space as others. This habit is relatively strong and of extreme evidential value (Harrison, 1958). Saxena and Singh (1992) carried out a study in spacing habit between letters in a word, between words and between the lines of writing. They reported that this characteristic showed peculiarities as it varies between individuals.

Alignment of letters or a total handwriting relative to a ruled or imaginary horizontal baseline is described as highly characteristic of individual writers as stated by Alkahtani and Platt (2010) and it is largely dependent upon the movement, manner of holding the pen and the design of letters (Lee and Abbey,

1992). Departure from accurate alignment will occur with a particular figure or letter and perfect alignment is not very often achieved, even when ruled paper is used (Foley, 1979). In his study of baseline alignment, McClary (1997) mentioned that the alignment of whole unlined sentences was for the most part varied in the writing of twenty nine persons. On the other hand, regardless of whether ruled or unlined paper was used, variation regarding this habit was often found amongst individuals.

As people appear to vary freely in their habitual slope, variation is frequently encountered in the slope of handwriting. A large difference was also found in the slope measurement between the handwriting of males and females (Totty, *et al.*, 1983).

The variability of letter forms or the general appearance of the writing among individuals and consistency of letter forms in one individual's writing are the concern of the Document Examiner in respect of writing identification (Crown, 1987; Lee and Abbey, 1992). In addition, variation between individuals and variation within a single person's writing are the central issue in handwriting comparison (Eldrige, *et al.*, 1984). Miller (1972) stated that document examiners are usually concerned with making a decision about the significance of a particular letter when it is varied from the system in design. This is because natural variation is the problematic factor, as it cannot be measured using a particular scheme and it is the result of several influences. As style and writing speed have significant effect on both pictorial appearance and physical characteristics, variation will occur in the handwriting of an individual. Therefore suitable control specimens are most important in order to avoid erroneous interpretation (Leung, *et al.*, 1993).

The amount of variation is much dependent upon the circumstances under which the handwriting was executed such as the writing instrument, the used surface and writing speed. In addition, variation to some extent is wider with some characters compared to others as a result of the structure of those characters. Huber and Headrick (1999) stated that some of the discriminating elements of writing exhibit much wider variation than others. There is a relationship between the level of education, skill and practice and variation with the greater the level of those three factors, the less variation and vice - versa. On the other hand, the more the hand is practised or the more skillful, the writer, then the more consistent is the product and this is more limited to the range of these variations (Huber and Headrick, 1999).

Ellen (1993) reported that a complicated action such as the manipulation of a pen into universally recognizable shapes, using a combination of the muscles of the arm, hand and fingers controlled by the brain both consciously and unconsciously, is clearly likely to give rise to wide variations in method and effect. The method of construction and proportion of each individual letter can show enormous variation even within one general style of writing. In cursive writing, some letters can be constructed in several ways. Different methods of construction or movement of the pen produce different shapes to the letter. Variation can also be caused by the connections between letters. The dot can be notably variable, apart from its position, which can be high or low or to the left or to the right, it may be written as a line, a small v, as a circle or not at all (Ellen, 1997). Still, the variation over a lifetime for one person is normally less than the variation between people (Bell, 2008).

Some people tend to write in a large size in normal circumstances. However, they alter the actual size of their writing due to the speed of writing or when only a limited space is available and a lot of information has to be written. Other people reduce the size of their handwriting to be extremely small to deliberately make it difficult to be read. Thus, the Forensic Document Examiner cannot rely on the size of the handwriting as an identifying feature of any great value. This is because there are several factors that affect the size and cause variation to be apparent between individuals and within individual writings. Wilson and Harrison (1958) stated that variation in relative size of letters and parts of letters may play an important part in the comparison of handwriting making it necessary for the FDE to understand and relate the various factors that influence handwriting.

Handwriting variation may also be influenced by gender. A number of studies have investigated this with the intention of gender prediction based upon handwriting characteristics. The average rate of correct identification of gender in these studies is around 70% as mentioned by Alkahtani and Platt, (2011). Al Haddad *et al.* (2009) examined a collection of Arabic signatures. They identified significant differences between male and female in data for some of the examined features such as number of strokes, number of dots, height and length. Variation according to demographic parameters, such as gender, is an area of great interest in the forensic and legal community. Knowledge in regards to the influence of this variable may provide useful assistance in reducing a given population of suspect writers, notably in cases involving anonymous writings (Taroni, *et al.*, 2012).

The ability to recognise and differentiate characteristics common to a particular group of writers from those specific to one individual is of paramount importance to the examiner of questioned documents (Muehlberger, 1989).

1.5 FACTORS THAT INFLUENCE HANDWRITING

However, those who learn to write are influenced by many factors, such as the teacher, family and friends in their early stages of the learning process. Moreover, as Srihari *et al.* (2002) reported, several factors may influence handwriting style: age, ethnicity, handedness, the system of handwriting learned, subject matter (content), writing protocol (written from memory, dictated, or copied out), writing instrument (pen and paper) and changes in the handwriting of an individual over time.

Since handwriting is a dynamic activity and not a product of a machine, but is the product of a human, many variables or factors are expected to interact in such production. The writer's fingers, hand, wrist and arm are in constant motion while writing is under execution and this can affect how a person writes (Morris, 2000).

These influences affect such acts in certain ways and under particular conditions. Bradley (1986) stated that the handwriting characteristics which differentiate the writing of one individual from that of another have been attributed to several factors, for instance the writer's emotions, motivations, perceptual abilities, physiology, intellectual development, musculoskeletal system and nervous system. It is obvious from this statement that these influences concern internal factors of the writer and are changeable rather than rigid.

Baxter (1966) noticed that a person may deliberately change a writing form to create a different appearance for many reasons. Many factors can influence handwriting which could be either deliberate or accidental. Some are easily accounted for whereas others cannot be explained. These factors can be divided into two categories; internal and external, that is, physiological (and factors affecting them) and physical factors, respectively. As explained in the following paragraphs, the internal factors include illness, drugs and alcohol, impairment of vision, old age, mood states, medication, stress and the health of the writer (Behrendt, 1984), whereas external factors may include environment, family, friends, relatives, training (copybook styles), natural ability, physical condition, writing position, writing surface and writing instruments (Davis, 2007). In addition to these influences, some occupations and level of education have an effect in writing, as Saudek (1978) pointed out. However, as Morris (2000) stated, the amount of formal education the person has is not necessarily related to his level of graphic maturity. In addition, different factors can influence different people in different ways (Huber and Headrick, 1999). Despite a variety of influences, however, handwriting remains a relatively enduring and automatic behaviour which has been found to be reliable and consistent once the author achieves maturity, unless influenced by chemicals, injury or poor health (Bradley, 1986). The many elements surrounding writing execution influence its production. There are other factors that can affect writing, such as mental illness, emotional states, even moods and physical handicaps due to the loss of use of the accustomed writing hand (Koppenhaver, 2007).

The following sections explain internal and external factors that influence handwriting.

1.5.1 Internal factors

The most common internal factors that influence handwriting are a) the writer's state of health and age, b) vision difficulty of the writer, c) writer's state of intoxication and d) the consciousness of the writer (concentrating in the act of writing). These factors are described in detail in the forthcoming section.

A. The writer's state of health and age

The act of writing starts in the brain as a mental picture of characters and words, then it is sent through the nervous system and muscles to the arm and hand. Morris (2000) stated that writing is actually a brain function and the hand is merely a device with which to carry out the instructions sent to it by the brain.

Illness, physical or mental disorder in either brain or hand may produce significant effects in handwriting. As such, if writing ability has deteriorated badly, letter design, ratio between tall and short letters, slant and alignment of the signature to ruled lines all lack stability (Hilton, 1969). Rosenblum, and Livneh-Zirinski (2008) concluded that an evaluation of both handwriting process and product characteristics among children with developmental coordination disorder (DCD) provides a more comprehensive picture of their deficits.

Kelly and Lindblom (2006) mentioned that advanced age could cause greater variations in handwriting as it is generally accompanied with declining health. Also, the writer could, over a period of time, introduce a new feature in his handwriting which extends the normal variations (Kapoor, 1985).

It is not always possible to distinguish, from the writing alone, between permanent and temporary impediments. Some temporary impediments may

affect writing more than permanent ones, but it depends upon the writer and the nature of the temporary impediments (Morris, 2000).

Not all illnesses affect handwriting. This is particularly true for those of short duration. Similarly, Koppenhaver (2007) mentioned that mental depression affects the handwriting but does not diminish or destroy the habitual characteristics.

Ellen (1997) stated that some signatures on disputed wills are either written in a time of severe illness or are claimed to be so. Comparison of these with signatures written in good health will reveal great differences, either because of illness or because a different writer has been involved. It is important to consider the two possibilities. The effect of ill health on writing is dependent on the type of the disease and its degree. If the illness occurs during old age, the chance of the writer producing an unusual or infirm signature is very high (Hilton, 1969). In some circumstances, when the writing is abnormal, the Forensic Document Examiner needs to know about the medical history of the subject during the course of handwriting examination. There are two reasons for this, one of which is that the mental and physical conditions of the writer cause an effect on his writing. The other reason is to permit the FDE to reach a better evaluation of the differences in the writing's appearance and to provide similar conditions during sample collection.

B. Vision difficulty of the writer

Writing can be influenced by impairment of vision or blindness (Ellen, 1997), which may cause several learning and writing difficulties that result in different manifestations of abnormal handwriting (Plimmer, *et al.*, 2011). There are certain features that might be found in the writing of this category, such as

oscillation of the writing line, many pen lifts, poor quality, notable hesitations, lack of coordination, uneven spacing between words and other errors (Walton, 1997). These symptoms can be found in the handwriting of blind people and those who learned to write with normal sight and lost their vision in a later stage of their lifetime. For example, to overcome the difficulty of writing words on a straight line, some visually handicapped writers use a straight edge implement like a ruler as a guide (Morgan, 1991). However, difficulty of writing on the exact line can also be found in the writing of those other than poorly sighted people. The mentioned handwriting features of blind individuals or poor vision are very important to the Forensic Document Examiner and are of high identifying value.

C. The writer's state of intoxication

Some substances, such as alcohol and certain drugs, affect the central nervous system and cause significant effects on handwriting. Koppenhaver (2007) mentioned that alcohol reduces inhibitions causing larger, more rapid handwriting. As the level of intoxication increases, the writing becomes more blurred, with the occurrence of extremes in spacing and size. As a result, writing of individuals who are under the influence of either drugs or alcohol will become abnormal due to the changes in the writer's ability with regards to control of the pen movement (Foley, 1979). Kelly and Lindblom (2006) stated that a person decidedly under the influence of either alcohol or drugs usually does not write in a normal fashion. While some of these impaired writers can produce an almost normal signature, most people find their writing coordination badly weakened and their signatures erratic and very significantly different. This depends, however, on factors such as the amount and concentration of such intoxicants. The writing of addicts and alcoholics will be affected by high concentration of drugs (due to tolerance effects) and also by the discomfort caused by its

withdrawal (Ellen, 1997). In addition, as people are influenced differently by alcohol and drugs, the effect of these substances in their writing vary accordingly and unpredictably.

D. Consciousness (Concentrating on the act of writing)

Handwriting is a complicated process. It requires ability and skills, and must be executed without conscious effort in order to be regarded as a normal writing. The act of normal writing is a combination of a variety of factors including the writer's perceptual abilities, physiology, musculoskeletal system, nervous system, intellectual development, emotions, and motivations (Bradley, 1986). Normally, when a person wants to write, emphasis is laid on the subject rather than on the act of writing. In other words, it is not required to consciously think about how to form characters and words; the brain and muscles would automatically construct them (Storer, 1997). So, unless we deliberately instruct our muscles to do otherwise, they will consistently reproduce our own handwriting features time after time within our own personal range of natural variations (Ellen, 1997). Morris (2000) defined a writer as one who is able to concentrate on the contents of what he is writing and not on how he makes his pen movement. On some occasions, the writer deliberately tries to change his writing and create a new style of different appearance for reasons such as disguising his normal writing features. In such a case, the writer produces his writing consciously and pays attention to the appearance of the formation of the letters. If that happens, the writing will be abnormal as changes will occur in writing appearance, particularly in line quality and it may not be valid for identification purposes. However, sometime abnormal writing can occur accidentally, due to external factors during the act of writing such as being engaged in a telephone call or some other sudden event.

During handwriting identification, the Forensic Document Examiners must do a proper evaluation of the handwriting under question in order to decide first whether it is normal or abnormal. If the writing is abnormal, again, he has to determine if it is accidental or is a result of deliberate change, for example, disguise or imitation (Alford, 1970). This will help the examiner to conduct the examination accordingly.

1.5.2 External factors

There are several external factors such as a) Familial characteristics, b) environmental effects, c) writing surface, position and paper and d) writing instruments that have an effect on the act of writing. These are explained below.

A. Familial characteristics

The handwriting features produced by an adult are sufficiently distinctive to be distinguished by the Forensic Document Examiner from the handwriting features of another (Van der Plaats and Van Galen, 1991). The only exception to this fact is the presence of similarities in the handwriting of some very closely related persons such as identical twins (Peebles and Morris, 1986). Handwriting of an individual could be influenced by his family, relatives, friends or the group to which the writer belongs. The reason for this being that as a child he or she first tries to learn how to write by imitating or copying the writing of his or her parent, brothers, sisters or teachers. Also, this influence could occur when parents exert undue pressure on their children to write in a particular way or to use a certain style. In such cases, the child acquires common writing features that are shared by the family members, and therefore, are called Familial characteristics. The same could be said regarding some categories or groups of people that present the same class characteristics peculiar to given categories, for example, engineers and medical practitioners. In addition, as Koppenhaver

(2007) stated, people from different countries also share some common characteristics resulting from the system of writing they were taught.

Familial characteristics are common to relatively small numbers within populations and could be used by Document Examiners in narrowing the search to a certain level. Hence, the examiner should be aware of such characteristics in order to distinguish them from individual characteristics.

B. Environmental effect

The environmental circumstances can have some effect upon the nervous state of some individuals and fluency in the writing may suffer. Studies have also shown that fatigue and weakness have their effects upon the control of the writing instrument and that writing performance may be affected in unpredictable ways (Huber and Headrick, 1999).

Poor lighting that may cause difficulty for the writer in following a line is a factor of environmental circumstances. Moreover, inconvenient surroundings, such as writing in cold or hot places will result in writing of a poor quality. An appropriate sample for handwriting identification is one produced when the writer is comfortably seated in a chair at a desk and when he is feeling calm and rested.

In addition, characteristics of the writing situation exert a powerful influence on the appearance of the written specimen. A signature written at a busy check-out when the author was rushed, tired, or distracted, may vary considerably from a signature written on a piece of personal correspondence when the author was relaxed or attempting to create an impression (Naftali, 1984; Saudek, 1978). Furthermore, the ability and skill that have been gained by the writer are considered to be important factors that permit him to overcome

any environmental difficulties he may face during the writing process. Thus, the environmental effect on writing can produce difference results.

C. Writing surface, position and paper

The position of the surface on which writing takes place can itself rather than that of the writer affect the result (Ellen, 1997). Normal writing can be achieved only in ideal conditions, such as in a horizontal position, on a smooth and stable surface and sitting on a chair. However, in some circumstances, writing may be made on a variety of abnormal surfaces such as rough or soft surfaces, glossy paper or in unusual positions - while standing, walking or sitting on a moving object like a moving train or car. When writing is produced in certain moving vehicles, regardless of whether it has minor or major impact, the formation of characters will appear erratic throughout the writing. Also, if the writing, for instance, is executed on a rough surface like a wooden surface, it is likely to produce shaky writing, whereas writing on soft surfaces, such as on cloth, will affect the normal pen pressure. Similarly, writing in a vertical position also has the same effect. For instance, when writing is done on a wall, the resultant writing will be of poor quality. As such, the quality of the final product of writing is dependent on the surface and position used. The Forensic Document Examiner has to take into account the circumstance in which the handwriting was executed; otherwise, the resulting findings will be incorrect. For example, the FDE has to determine the manner of execution of the writing in question - whether the writer was sitting, standing or lying down when he or she wrote the document - because this makes a difference in terms of writing quality as a result of the change caused in the handwriting by the affected orientation and ink flow. There are a variety of papers which are used for writing purpose, some of which are of poor quality, which can cause an effect in the writing in by

making it difficult to use the pen properly. For instance, porous paper allows ink to soak into the paper and hence the writing could become illegible.

D. Writing instruments

The writing implement used can have an effect on the appearance of the handwriting – a ballpoint pen compared to a thick felt tip marker, for example. Therefore, during their casework or scientific research, some Forensic Document Examiners ask the subject to use a specific writing instrument such as ballpoint pen or fountain pen in order to get a good handwriting sample or to provide the same conditions as that of the document under examination. Other experts leave the choice of pen to the individual. Despite the variety of writing instruments, little significant structural difference is found in the writing of one person when using different types of pens (Ellen, 1997). The good quality of the handwriting, to some extent, may rely on the writing instrument. Thus, some people prefer or insist on using a specific pen of a particular colour or shape in order to feel comfortable and produce their best quality writing, confirming that the choice of a pen has an effect on their writing (Goonetilleke, *et al.*, 2008). Others do not mind the usage of any pen of any colour, believing that the type of writing instrument has no affect on their resulting writing. Ravindra, *et al.* (2009) have investigated the effect of pen design on drawing and writing. They concluded that the pen design, whether sharp (triangular, square or circular) or heavy pen (large diameter) has an effect on comfort and writing ability but, the writing speed however, was not affected in the short test used in the study.

Also, it is correct to mention that any defects in the writing instrument will affect the output accordingly. For example, if the ink does not flow properly on to the paper due to broken nibs or ball rotation or for any other reasons, this will cause an adverse effect in the writing.

1.6 RESEARCH QUESTION

The literature described above shows that there are many factors that can impact on handwriting production. Some are external, such as, teaching methods used and some are internal, such as, the neurological capacity of the writer in terms of cognitive and motor capability. The interaction of these factors in a given writer are likely to be complex and in many ways unpredictable. Nonetheless, other researchers have found that, despite the interactions of such factors, some handwriting features may persist in such a way that it is possible to identify the country of origin of the writer. In some writers these may be very obvious but in others less so, reflecting the individual nature of the handwriting process and its learning experiences.

It has been established that, with regard to the Roman script, it is possible to determine the nationality of the writer of a passage of text or the region in which the writer was taught to read and write (Turnbull, *et al.*, 2010). A similar study of the possibility of identifying national or regional differences in writers using the Arabic script has not been recorded and published in a literature. The purpose of this study is to investigate this and to determine whether or not there are features of Arabic handwriting that can provide evidence to indicate national or regional differences.

The factors that affect handwriting production are likely to be the same irrespective of the script that is being used. Thus, the null hypothesis for this research is that there will indeed be such national or regional differences. The alternative hypothesis is that there will not be evidence of national or regional differences in the handwriting features in Arabic. Such a finding would lead to a

careful re-evaluation of the reasons that are put forward for such differences in the Roman script, such as cultural and educational variations by region.

Hence, this research will study samples of Arabic handwriting collected from individuals from Jordan and Oman (taken to be typical countries in the Eastern Arab world) and Morocco and Tunisia (taken to be typical countries in the Western Arab world) to determine the presence of any particular features or characteristics that may be common to individuals of a given nationality or Geographical area where they were taught to read and write Arabic in a particular country or region.

If the null hypothesis is supported, then another aim of this research is to describe the variation in letter formations used by individuals from, or educated in, the countries and regions being studied and to gain an understanding of variation in Arabic handwriting between individuals as an essential element in terms of handwriting identification.

This is important information for Forensic Document Examiners since handwriting features in one region may be commonplace but those same features may be far less frequently encountered in another region. This has the potential to assist the expert when interpreting the significance of handwriting features found in casework.

Any combinations of features that do show regional or national variations can be used to assess the likelihood of a given writer coming from a particular location. In other words, finding a certain combination of features might provide evidence to indicate the geographical origin of the writer.

Thus, this research was carried also to provide a mechanism that will show differences and indicate the origin of the writer. Such information, treated with appropriate caution, might be of interest to the relevant authorities in some case situations.

1.7 WORKING HYPOTHESIS

Are there regional and national differences (variations) in Arabic handwriting?

1.8 MAIN AIM

The main aim of this study was to ascertain whether there are variations, regionally and nationally in Arabic handwriting.

1.9 SPECIFIC AIMS

1. To undertake a thorough literature search in the area
2. To prepare a questionnaire and writing documents as material for collection of data.
3. To analyse each sample employing a different statistical tests
4. To present the data within as graphically or as tables
5. To analyse the data for statistical differences
6. To write the PhD thesis

CHAPTER 2

THE BASIC STRUCTURE AND WRITING SYSTEM OF ARABIC LANGUAGE

2.1 INTRODUCTION

This chapter introduces the reader to the basic structure of the language and a brief review of the history of the Arabic language. Also discussed are copybook styles which are used as aids to teaching how to write Arabic and which include an awareness of the principles of the language. This would be very helpful for Forensic Document Examiner, particularly, in situations when being asked to examine a case involving a handwritten Arabic text.

Arabic ranks as the sixth language of the world in terms of numbers of native speakers, with the other five above it being Chinese, English, French, Russian and Spanish. In 1973 it was recognised by the United Nations as an official language (Holes, 1995).

Arabic is the native tongue for over 325 million people, and is the national and official language in 22 Arab States (Assaleh, *et al.*, 2009). These countries include Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen stretch from North Africa in the West to the Sultanate of Oman in the East and from Sudan in the South to Syria in the North (Smart, 1992).

Arabic is the spoken and written means of communication of all native Arabic speakers (Holes, 1995). Arabic is also spoken and written by some non-Arab Muslim people since Islam's Holy Book, the Qur'an, which is written in Arabic. Arabic is thus the religious language of all Muslims irrespective of nationality. Many Muslims in Asia and Africa have therefore learned Arabic to various levels of proficiency as a venerated religious language (Holes, 1995).

Orientalists concerned with Middle Eastern civilizations also learn Arabic as part of their culture. Furthermore, large communities of Arabic people exist in non-Arabic speaking countries in different parts of the world where Arabic is not an official language, but they still use Arabic in their business and in daily affairs. Moreover, languages such as Farsi and Urdu use Arabic-like script for writing (Assaleh *et al.*, 2009). However, a number of other native languages beside Arabic are also spoken in some Arabic countries; these include Mahri in the South of The Sultanate of Oman, Kurdish in Iraq and Berber in Morocco.

As a result of the constant contacts with other nations, cultures and the translation process into Arabic from other languages, Arabic has been influenced by other languages, and hence, has borrowed many new terms and vocabularies which is known as coinage (Bakalla, 1984).

In the countries of North Africa, however, there are several million people whose mother tongue is one of the large numbers of Berber dialects which are only distantly related to Arabic. Virtually, all these Berber speakers have at least a rudimentary knowledge of local spoken Arabic and most of them are bilingual (Holes, 1995), resulting in an external influence in their usage of Arabic language.

Despite the several and different spoken colloquial dialects throughout the Arab world, written Arabic is the same (Peters, 2007), and Arabic will remain preserved from undergoing any changes as the Holy Qur'an is the driving force behind the maintenance of Classical Arabic as the standard par excellence for the Arabic language (Bishop, 1998).

Arabic is regarded as the richest in linguistic literature and considered the most primitive form of speech extant among the Semitic languages. It has

three different forms, namely, colloquial or spoken Arabic dialects, formal or Modern Standard Arabic, and classical Arabic (Abboud and McCarus, 1989).

The colloquial dialects are spoken in informal conversation in day to day life. In addition, some writers use the dialect when they write dialogue. There are great variations in dialects, from one Arabic country to another, and each country has its own colloquial forms. There are large differences between dialects and many are mutually unintelligible. The Omani colloquial, for example, differs from the Tunisian, and the Lebanese from the Egyptian. Moreover, colloquial dialects vary within the same country; thus the Northern Omani dialect differs from the Southern dialect, and both differ from the Eastern dialect. Dialects are therefore a good tool for determining the region the speaker belongs to. Also, the written form of the dialect can be useful evidence in identifying geographical origin of the speaker and writer (Bakalla, 1984).

The classical form is the contemporary Arabic of the time of Prophet Mohammed and it has the style and vocabulary of that time. This form is considered to be the language of the Qur'an and is not used in conversations but only to write, read and recite Qur'an.

Modern Standard Arabic (MSA) is the official means of communication throughout all Arabs states, either between each other or within the same country. MSA is used on official occasions, and in education, books, official correspondence, news bulletins, official documents, magazines and lectures for example. It is consistent across the national boundaries in its written form.

2.2 A BRIEF HISTORY OF ARABIC LANGUAGE

Arabic is a member of the semitic subgroup of the Afro-Asiatic group of world languages (Bishop, 1998) having a long history stretching back thousands of years (Bakalla, 1984).

Languages are divided into a number of families such as the Roman and the semitic. Arabic has descended from a language known in the literature as Proto-semitic and its roots are clearly founded in a Semitic predecessor. The home area of "Proto-semitic" is still not exactly known among Scholars; however, nowadays many of them believe it originated somewhere in East Africa (Terri, 1999). Similarly, the origin of the semitic languages is not clearly known but most linguists consider that the Arabian peninsula or Mediterranean basin area is the home of this family (Hole, 1995).

Arabic appears to be the youngest of all among today's semitic languages. While many of the semitic languages such as Syrica, Akkadian and Phoenician are now considered extinct languages, Arabic has flourished and no major changes have occurred in the language since the seventh century AD (Burrow, 2004). Many factors have contributed to preserving the language from undergoing major changes, and these include the Holy Book of Muslim, The Qur'an, and the continuous literary output over the long period; this is considered to be one of the greatest achievements of civilised man (Smart, 1992).

There is no agreement among Scholars with regard to the origin of the Arabic language; the same situation can be said about the invention of the Arabic writing. The invention of a writing system came about because of the need for written records of human activities, and the development of such

system was gradual and occurred relatively late in human history (Fromkin, 1998). There are many theories about the invention of writing without precise determination of where and when this occurred. However, the development of writing is attributed to the Sumerians, the people who built a civilization in southern Mesopotamia, which is now Iraq. The source of this information is the documents left by Sumerians more than six thousand years ago. These documents comprise several clay tablets, which are immensely valuable as they contain written records of different aspects of life at the time, such as business, religion, literature and poetry (Bakalla, 1984).

Over the Centuries the original form of communication known as pictography (or what is called picture writings or picture representing a word or drawings of the objects) was simplified and conventionalised and the characters or symbols were produced by using a wedge-shaped stylus that was pressed into soft clay tables. This system represented the words of the language and became a syllabic and logographic writing system. Syllabic is another stage in the development of writing in which a given a symbol is used to denote a syllable of the word (Bakalla, 1984), whereas, logographic (representation through logos) is the usage of a certain symbol to represent the meaning of the whole word or phrase. Later, the use of characters to form words was developed by the Phoenicians around 1500 BC who were familiar with both the Sumerian and Egyptian writing systems (Fromkin, 1998).

The time at which Arabic writing was first used is not known. However, it was certainly shortly before the advent of Islam (Van - Dyck, 1894). Historically, the earliest extant copies of which date to the 4th century B.C., has descended from the Nabatean Aramaic script. However, because the Aramaic script

represented less than the required number of consonants for Arabic, the use of some shapes was extended by the means of dots placed on the letters (Burrow, 2004).

Such extensions to the letters are very prominent in those groups of characters that have similar shapes such as in Ta (ت) and Thaa (ث), having two and three dots, respectively. This behaviour of forming a different character is noticeable in letters such as Ha (ح) without a dot, Kha (خ) with one dot above the letter and Jeem (ج) with one dot below the letter. Dotting habits as described later in this chapter are considered an important feature of Arabic language.

2.3 BASIC CHARACTERISTICS OF ARABIC HANDWRITING

This section provides the reader with a brief explanation of most commonly encountered characteristics in Arabic written text that could help in understanding the non-alphabetical writing features of Arabic handwriting. Arabic is written from right to left and both handwritten and printed Arabic text have more or less the same style from the point of view of connected or disconnected characters (Amin, 1998). In other words, the twenty eight characters of the Arabic alphabet, except the dividing letters as explained later in this section, are written in a cursive fashion, regardless of whether they are handwritten or typed. In contrast, in Latin script, characters may be found either in connected or disconnected forms when they are hand written and are unlikely to be found in connected forms in a printed text.

Arabic letters do not have a special form, or what is called upper case letters, like that which is used in the English alphabet at the beginning of sentences and proper nouns. Arabic characters are written in identical design in all Arabic countries although the dialects used amongst these countries might

be different. The Arabic script, whether it is handwritten or machine printed, can be achieved in different styles: Naskh, Riqa and in artistic or decorative style (e.g. Kofi). Kofi style is so-called as it was undertaken and developed in Kofa, Iraq, and it is more decorative and used in The Qur'an in manuscripts. Handwritten Arabic text can be found in both styles in either Naskh or Riqa, but the typed written is normally in Naskh style.

As Arabic script is cursive, the letter formation has special features as many characters possess several different forms. The form of the letter depends on whether it is connected or disconnected, or if it is connected, upon its position in the word, (i.e. whether it is connected to a preceding or following character).

The shape of an Arabic character depends on its relative position in the word. Some characters might have up to four different shapes depending on their position (beginning, middle, end and unconnected). For example, the character Ghain (غ) - this character has a beginning shape (ـغ), middle shape (ـغـ), ending shape (غـ) and unconnected shape (غ) (Amin, 1998).

The Arabic alphabet contains six dividing (non connector) characters (ا , د , ذ , ر , ز , و). These occur in Arabic script in two positions, either unconnected to any other letters or connected to the preceding letter. As a result of these dividing characters, a word can be divided into smaller sections, which are called syllables. Each of these sections could include two or more letters. The other twenty two characters are always connected to a following letter, and their shapes change according to whether they connect to the preceding or following letters.

2.3.1 Dotting

There are 15 characters in the Arabic language that have to be dotted, comprising more than half of the Arabic alphabet characters (Table 2.1). These dots are used as part of the characters and are very important distinguishing features between otherwise identical letters. The designs, numbers, and position of dots vary from one character to another. Dots are systematically used to differentiate between letters which have the same form and for the purpose of pronunciation (Awaidah and Mohamoud, 2009). Without these dots, misrepresentation of the characters will occur. These dotting patterns vary in their position, located above or below the characters (e.g. **ب، غ**). In addition, dots also vary in their number and some are marked with one dot above (**خ**) or one dot below (**ج**), while others have two dots above (**ت**) or two dots below (**ي**) or three dots above (**ث** and **ش**).

Table 2.1: Dotted Arabic characters with different dots

No. of Dots	Dotted Characters
Single	ب، ج، خ، ذ، ز، ض، ظ، غ، ف، ن
Double	ت، ق، ي
Triple	ث، ش

2.3.2 The identical shapes (similarly-shaped characters)

An important feature of Arabic script is the identical shapes of certain characters, such as **ب، ت، ث** and **ج، ح، خ**. Table 2.2 shows the Arabic characters that are written exactly alike, except for the usage of dots above or below each of them.

Table 2.2: Arabic characters of identical shape

Sr. No.	Identical Characters
1	ب، ت، ث
2	ج، ح، خ
3	د، ذ
4	ر، ز
5	س، ش
6	ص، ض
7	ط، ظ
8	ع، غ

2.3.3 The glottal stop – Hamzah (ء)

The sign (ء) is called Hamzah and it is not an alphabetical character but is considered as an orthographical sign shown in Table 2.3.

Table 2.3: Usage of Hamzah (ء)

Example	Character	Position
أسعد ، أفلح	(أ) Alif	Beginning (above)
إيمان ، إنسان	(إ) Alif	Beginning (below)
يسأل ، فلوثة	(أ) Alif	Middle
مؤذن ، مؤدب	(ؤ) Waw	Middle
صائم ، قائم	(ئ) Yaa	Middle
خطأ ، قرأ	(أ) Alif	End
تباطؤ ، يؤذي	(ؤ) Waw	End
ممنون ، يعذب	(ئ) Yaa	End
إجراء ، المرء	(ء) Hamzah	Independent

It's main function is to indicate the proper pronunciation of the word and it can be written according to the following principles:

1. At the beginning:

In classical Arabic, not like what is in the Holy Book Qur'an, if Hamzah has to be written at the beginning it is always written above the letter Alif (أ) or below it (إ) and no other character could be used as carrier of this glottal stop at this position.

2. In the middle:

In this case, Hamzah is always written above the related character and never below it. There are three carrier characters; Alif (أ), Waaw (و) and Yaa (ي) above which the Hamzah have to be written. If it is in the middle of the word, the letter Yaa is written without dots.

3. At the end:

Also, Hamzah is written at the end of the word and it always comes above one of the characters Alif (أ), Waw (و) or Yaa (ي).

4. Independent (without Carrier):

On some occasions, Hamzah is written alone on the line without any carrying letter in either position, in the middle or at the end and after certain characters such as Alif (ا), Raa (ر), Taa (ط) or Zai (ز).

2.3.4 Vowel signs (َ , ُ , ِ)

There are three signs which play an integral part in giving the proper sound, exact meaning and pronunciation to Arabic words. These are Dhamah (ُ), Fatthah (َ) and Kasrah (ِ). These vowels are marked in Islam's Holy Book, the Qur'an, as well as in children's copybook style and old-fashioned Arabic handwriting. However, these vowels are not used in modern Arabic text, regardless of whether it is typed or hand-written. Hence, these are not included in this study ضُنْ, شُنْ and تْ are examples of usage of these signs.

2.3.5 Other diacritical marks

The Arabic script contains some diacritical signs called shaddah and tanwin that are unique only to Arabic. The function of these marks is to indicate the proper pronunciation of words, possibly their meaning and to avoid the repetition of certain characters within the same word thereby reducing the size of writing. These diacriticals are used in formal documents and rarely used in informal ones, (Al-Ohali *et al.*, 2003).

1. Shaddah (ّ)

This sign is used only in two positions when written along with a regular character: in the middle or at the end of the word and it is not used at the beginning of any Arabic word. The shape of this sign is similar to that of the character seen (س) or sheen (ش). These are some examples of shaddah (عَمَّ , حَكَّم , عَقَّ).

2. Tanwin (ً , ٌ , ٍ)

Tanwin takes three different forms and it is the double of Dhamah (ُ) like in the word (مَعْلَمٌ) , Fathah (َ) like in the word (مَعْلَمًا) or Kasrah (ِ) like in the word مَعْلَمٍ ; this depends upon the grammatical situation of the word. Thus, it can be noted that Tanwin has no effect on the structure of the characters within the word. However, if the Tanwin is of Fathah, then the character Alif has to be added to the end of the word, as is shown in the example above.

2.3.6 The sign – Maddah (~)

The sign Maddah is frequently used in both typed and handwritten texts and pronounced 'aa. Maddah has the function of giving the exact sound and

pronunciation to the word and it is written only above the character Alif (آ) in two positions; at the beginning like in the word، آمال and in the middle like in the word قرآن.

2.3.7 Letter formation

Arabic letters have different forms or shapes according to their position within a word. This feature is, extended to the scope of both class and individual characteristics. However, because of the way in which Arabic handwriting is constructed as cursive writing it has the disadvantage of being difficult to classify compared to block handwriting because of the effects of the preceding and following characters (Hardcastle *et al.*, 1990).

In addition, there are in Arabic alphabets two letters that have a similar sound. These are Dhad (ض) and Za (ظ). These create confusion for some people, especially those with lesser competence, resulting in errors as a result of interchanging the characters.

Furthermore, there are some Arabic words that are written in a way which differs from the way they are pronounced. For instance, the word هذا and the word ذلك. They are pronounced as if they contain the letter Alif in the middle of each of them but are actually written without it and some people do confuse between the character ت and the character ة and between the latter and the character ه.

2.4 INDIVIDUAL VARIATIONS

This section describes certain aspects of writings where variations may occur within individual writers with regards to certain characteristics, such as,

the shape of the glottal dots, their positions in relation to the character and writing quality.

Different writers exhibit different shapes of the dots, particularly the double and triple dots, and in their positions. For instance, when some individuals write the double dots they join them as a dash (—), circle (∞) or curve (∪) or they write each dot independently from the others (..). Also, variation is notable between writers in respect to the shape of the triple dots; some of them execute the shape of these dots (∧) similar to Indian numeral eight (8), others make them as (~) while others write them independently from each other (ˆ). Variations also exist in the position of dots of all three types, as some writers put the dots in the exact position, while others put them to the right, or to the left, far below or above the related characters. In addition, variations also occur between individuals in respect to the size of the dots, as some write dots close to the size of writing standard, whereas others write them relatively smaller or bigger. Furthermore, some people neglect to put dots on certain characters particularly the character (ي), whereas others, particularly those with a lower level of education, put dots under a wrong character. This confusion happens as some words consist of dotting character but do not need to be dotted in a particular context; for example, the word **على** meaning “on”, must be without dots but if it refers to the name “Ali” **علي**, it must be dotted. If this feature occurs and is regularly found in the questioned document, it could be used as an identifying property. However, people of some Arab countries such as Egypt and Sudan, do not use dots under certain words, such as **الذي**, **معاني** and **كتابي** (Nassar, unpublished).

People also vary in respect to the use of Shaddah (ّ) and Tanwin (ً), as some writers, old people in particular follow the copybook standards and put these signs where they should be above or below the related character, whereas others are careless and never use any of them. These marks add important features to Arabic handwriting and are considered to be of high value in identifying a person's writing.

Hamzah (ء) is an important non alphabetical character and is very often present in Arabic text. Its size, shape and position above or below the carrier letters vary between individuals. Furthermore, a large number of Arab writers face difficulty when they have to use Hamzah, particularly in some positions in the words, leading to spelling mistakes on many occasions. Therefore, it is essential for the Forensic Document Examiner while examining the Arabic writing, to take into consideration the glottal stop - Hamzah - and use it as an identifying characteristic.

Similarly, executing the Maddah (~) sign varies in shape and size between writers. In addition, some people get confused between the glottal stop – Hamzah (ء) and the Vowel sign Maddah (~), resulting in writing Hamzah instead of Maddah in some positions. As such, this could be regarded as an identifying feature of the Arabic handwriting when it exists in the text under examination.

2.5 SOME CONSIDERATIONS FOR FORENSIC DOCUMENT EXAMINER (FDE)

The above described features make Arabic handwriting distinctive and are an important consideration for the handwriting expert. Since these features are frequently encountered while writing, each writer has his own method of executing them. In addition, one of the important points that needs a mention is that the dots often remain intact when the actual text is disguised. Deviations from the writing style regarding dots are considered to be individual characteristics and as such, will provide valuable information toward handwriting identification. Consideration of dotting characteristics must be taken into account when Arabic handwriting examination is undertaken.

As previously noted, Arabic script is a cursive script and the letter formations have special features as many characters possess several different forms. The form of the letter depends on whether it is connected or disconnected, or if it is connected, upon its position in the word, (i.e. whether it is connected to a preceding or following character). This gives the FDE the opportunity to have many alternatives, regardless of the character, as the shape of the letter is the same and within the same group. As such, the FDE can depend on one of the identical characters during a comparison. For example, the FDE can compare character (ح) with character (ح) or character (ع) with character (ع) and, hence, could reach a satisfactory result.

Arabic handwriting merits special consideration for the FDE (Levinson, 2001). The Arabic alphabet has significant characteristics which increase the identifying features of Arabic handwriting. In addition, the errors that are committed by Arabs themselves are crucial and of evidential value and could be

used by FDE during the handwriting examination and they would help in narrowing the search or would give support in drawing conclusions.

2.6 ARABIC COPYBOOK STYLE

As with any other language, the Arabic alphabet has a copybook style as shown in Table 2.4.

Table 2.4: Arabic alphabet (Copybook style)

Character	Unconnected form	Connected forms			Examples		
		End	Middle	Start	End	Middle	Start
Alif	أ	ا	ـ	ا	مرحبا	ـ	الود
Ba	ب	ب	ـب	بـ	حب	محبّة	بريق
Ta	ت	ت	ـت	تـ	سبت	ستجد	تيسير
Thaa	ث	ث	ـث	ثـ	بث	يثير	ثواب
Jeem	ج	ج	ـج	جـ	حج	مجمع	جميل
Ha	ح	ح	ـح	حـ	ينبح	محمد	حوي
Kha	خ	خ	ـخ	خـ	مخيخ	يخون	خان
Dal	د	د	ـ	د	سعيد	ـ	دوام
Thal	ذ	ذ	ـ	ذ	نبيذ	ـ	ذلك
Ra	ر	ر	ـ	ر	بصير	ـ	رحيم
Zai	ز	ز	ـ	ز	غريز	ـ	زبيدة
Siin	س	س	ـس	سـ	قيس	مسرّع	سيارة
Shiin	ش	ش	ـش	شـ	مشمش	مشمس	شمس
Sad	ص	ص	ـص	صـ	رخيص	مصلّى	صديق
Dhad	ض	ض	ـض	ضـ	مكتض	يضحك	ضحوك
Taa	ط	ط	ـط	طـ	غيط	يطبق	طريق
Za	ظ	ظ	ـظ	ظـ	غيظ	يظهر	ظهر
Ain	ع	ع	ـع	عـ	يبيع	معبّد	عمل

Character	Unconnected form	Connected forms			Examples		
		End	Middle	Start	End	Middle	Start
Ghayn	غ	ـغ	ـغـ	ـغـ	يسينغ	بيغني	غدير
Fa	ف	ـف	ـفـ	ـفـ	سيف	يفك	فلاح
Qaf	ق	ـق	ـقـ	ـقـ	طبق	سقيم	قميص
Kaf	ك	ـك	ـكـ	ـكـ	مفك	مكتوم	كريم
Lam	ل	ـل	ـلـ	ـلـ	مقيل	ملوم	ليل
Meem	م	ـم	ـمـ	ـمـ	حكيم	حمود	منتهى
Noon	ن	ـن	ـنـ	ـنـ	أمن	تنور	نور
Haa	هـ	ـهـ	ـهـ	ـهـ	الله	سهام	هواية
Waw	و	ـو	ـوـ	ـوـ	يسمو	—	واحد
Yaa	ي	ـي	ـيـ	ـيـ	علي	حياة	يجد

This style is always printed in a particular way and used for the purpose of teaching children when learning to write all across the Arab states. In addition, it could be used by anyone who wants to learn to write Arabic. It contains the characters, numerals and simple words which can be easily understood. (Nassar, unpublished). Copybook styles are subject to fashion and it is unusual to have one style for a long time throughout the Arabic world due to cultural changes over time. However, in the past there were no printed copybook styles that could be used to teach the learners the art of writing. As an Omani National, the author can confirm this to be true in Oman until 1970, as, in Oman the modern education system started after this date. Previously, there were no modern schools in the country; people learned writing, Arabic grammar and other religious sciences from a religious teacher. The old Omani writing style (Figure 2.1) is different compared to the present style (Figure 2.2).

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَدْ أَقَمْتُ سَعَادَةَ وَعَائِشَةَ وَرَأَيْتُ بَنَاتِ الْهَالِكِ سَعُودَ بْنِ عَلِيٍّ ابْنِ عَبْدِ
 عَبْدِ اللَّهِ بْنِ نَاصِرِ بْنِ خَلِيفِ بْنِ الْحَضْرِيِّ وَكَيْلًا لَهَا وَنَائِبًا عَنْهَا فِي مَحَاسِبِهَا
 وَكَيْلًا لَهَا الْمُتَقَدِّمَ حَارِبَ بْنِ رَاشِدِ بْنِ عَلِيِّ الْوَرْدِيِّ لِمَجْمُوعِ أَمْوَالِهَا مِنْذَانِ تَوَلَّى
 قَبْضَ هَذِهِ الْأَمْوَالِ الْآيَةَ الْمَشْهُورَةَ بِالْأَرْتِ مِنْ وَالِدِهَا الْهَالِكِ سَعُودَ بْنِ عَلِيٍّ
 إِلَى تَارِيخٍ يَبْعَثُ فِي هَذِهِ الْأَمْوَالِ لِسَعِيدِ بْنِ نَاصِرِ الْحَضْرِيِّ وَفِي قَبْضِ مَا تَجَمَّعَ
 فِي يَدِهِ مِنْ دَرَاهِمٍ مَحْصُولًا عَنْ هَذِهِ الْأَمْوَالِ قَبْضَ كُلِّ رَهْنَةٍ أَخَذَهَا لَهَا
 وَفِي الْمَحَاسِبِ وَالْمَحَاسِبِ إِذَا حَاجَ الْأُمْرَ إِلَى رَدِّهَا مِنْ شَاءَ اللَّهِ مِنْ حُكَّامِ الْمُسْلِمِينَ
 وَكَلِمَةُ تَوْكِيلاً شَرْعِيًّا ثَابِتًا وَأَقْبَنَهُ مَقَامَهُمْ وَأَنْزَلْنَاهُ مِنْزِلَةَ أَنْفُسِهِمْ
 أَوْ أَلَانَهُمْ بِذِكْرِهِمْ بِأَنَّ سَعِيدَ بْنَ نَاصِرِ الْوَرْدِيِّ بَعَثَ بِمَعْرِفَةِ مُحَمَّدِ بْنِ
 بْنِ نَاصِرِ بْنِ عَبْدِ اللَّهِ يَوْمَ ٧ جُمَادَى الْأُولَى ١٣١٥ هـ

Figure 2.1: Document written in old Omani handwriting style

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

قَدْ أَقَمْتُ سَعَادَةَ وَعَائِشَةَ وَرَأَيْتُ بَنَاتِ الْهَالِكِ سَعُودَ بْنِ عَلِيٍّ مِنْ أَوْلَادِ عَبْدِ
 عَبْدِ اللَّهِ بْنِ نَاصِرِ بْنِ خَلِيفِ بْنِ الْحَضْرِيِّ وَكَيْلًا لَهَا وَنَائِبًا عَنْهَا فِي مَحَاسِبِهَا وَكَيْلًا لَهَا
 الْمُتَقَدِّمَ حَارِبَ بْنِ رَاشِدِ بْنِ عَلِيِّ الْوَرْدِيِّ لِمَجْمُوعِ أَمْوَالِهَا مِنْذَانِ تَوَلَّى قَبْضَ هَذِهِ الْأَمْوَالِ
 الْآيَةَ الْمَشْهُورَةَ بِالْأَرْتِ مِنْ وَالِدِهَا الْهَالِكِ سَعُودَ بْنِ عَلِيٍّ إِلَى تَارِيخٍ يَبْعَثُ فِي هَذِهِ الْأَمْوَالِ
 لِسَعِيدِ بْنِ نَاصِرِ الْحَضْرِيِّ وَفِي قَبْضِ مَا تَجَمَّعَ فِي يَدِهِ مِنْ دَرَاهِمٍ مَحْصُولًا عَنْ هَذِهِ الْأَمْوَالِ
 وَفِي قَبْضِ كُلِّ رَهْنَةٍ أَخَذَهَا لَهَا وَفِي الْمَحَاسِبِ وَالْمَحَاسِبِ إِذَا حَاجَ الْأُمْرَ إِلَى ذَلِكَ
 عِنْدَ مَنْ شَاءَ اللَّهُ مِنْ حُكَّامِ الْمُسْلِمِينَ وَكَلِمَةُ تَوْكِيلاً شَرْعِيًّا ثَابِتًا وَأَقْبَنَهُ مَقَامَهُمْ
 وَأَنْزَلْنَاهُ مِنْزِلَةَ أَنْفُسِهِمْ إِفْرَارًا مِنْهُمْ بِذَلِكَ وَكَتَبُوا سَالِمِينَ مُحَمَّدِ بْنِ الرَّوَاحِيِّ بِيَدِهِ
 بِمَعْرِفَةِ مُحَمَّدِ بْنِ سَاجِدِ بْنِ نَاصِرِ بْنِ عَبْدِ اللَّهِ يَوْمَ ٧ جُمَادَى الْأُولَى ١٣١٥ هـ .

Figure 2.2: Example of present Omani style

The difference in styles of writing is very obvious when comparison is made between the handwriting of old people and that of the new generation (Table 2.5). This confirms that the writing styles are not only different from one country to another, but also change over time within a certain country.

Table 2.5: Some words representing the present and old Omani styles

Sr. No.	Printed Style	Present Omani Style	Old Omani Style
1	الأموال	الأموال	الأموال
2	أقمن	أقمن	أقمن
3	من	من	من
4	لهن	لهن	لهن
5	الهالك	الهالك	الهالك
6	هذه	هذه	هذه
7	بن	بن	بن
8	إلى	إلى	إلى

At the present time, the Arabic writing system consists of several different writing styles of Arabic scripts, like Naskh, Kofi and others (Awaidah and Mohamoud, 2009). The two most common of these styles are Naskh and Riq'a which are shown in Table 2.6.

Table 2.6: Examples of Naskh and Riq'a styles

Naskh	Riq'a
ق	ق
ك	ك
ث	ث
ن	ن
ز	ز
س	س

Naskh: This style is the simplest and is a classical type style used in handwriting, typewriting and printing. It is a popular writing standard among individuals. In addition, this style is used in the text books, newspapers, official correspondence and other such publications.

Riqa: This style is widely used, particularly in some Arabic Countries or regions and regarded as a modern handwriting standard. This writing model is somewhat faster to produce compared to Nuskhi style. However, it is rarely used in text books, newspapers or any other official documents.

CHAPTER 3

MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter described the materials and methods used for collection of samples, the contents of the samples, the procedures used to identify the samples and perform the character analysis using different statistical tests.

Multiple steps were taken towards the identification of the class characteristics (defined earlier) in Arabic handwriting. First and foremost were the collection 600 handwriting samples from nationals of four Arabic Countries, namely, Jordan, Morocco, Oman and Tunisia. Then, ten different characters and one word were chosen to be examined. Next, several forms of each character in different positions within words were extracted. All handwriting samples were examined for the selected class characteristics. Finally, four different statistical approaches and blind tests were used for the findings to be analysed.

3.2 SAMPLES

Six hundred samples of Arabic handwriting were obtained by distributing a survey containing a questionnaire, the actual sample text containing Arabic characters, Indian numerals and a typewritten Arabic text to participants from the four Arabic countries.

Taking account of the nature and mode of construction of Arabic characters, which are always written in a cursive (running) writing style, words in the text passage were chosen carefully. The aim was to include all alphabet characters and to represent each character in three different positions within a word: at the start, in the middle, and at the end or when written alone. This procedure was followed to ensure that the handwriting samples were

comprehensive and to achieve the aim of evaluating the complete range of variations between the four chosen countries in terms of the forms or styles of letters used.

One hundred and fifty participants were selected from each country spanning across different regions in these countries based on their availability and acceptance to participate in the sample collection process. This was done with the help of an individual from each country other than Oman (where the author managed the process) with clear instructions to select only participants in the age group of 18 and above and with near to equal number of males and females who have varied level of education. Each of the participants was contacted by these individuals either directly or through known acquaintances. The samples received were almost equally distributed between males and females: 50.5% male and 49.5 % female, and their ages were between 18 and 69. The age profile is explained later in the results chapter. Ethical approval for the study was given by both Royal Oman Police and the University of Central Lancashire Ethics Committee.

3.3 PROCEDURES

Individuals were required to fill out the questionnaire and copy the Indian numerals, the characters of the Arabic alphabet and the text passage in their own handwriting on white ruled A4 paper provided, as shown in Figure 3.1.

ثالثاً: يرجى كتابة جميع البيانات التالية:

أ - الأحرف الأبجدية

أ	ب	ت	ث	ج	ح	خ	د	ذ	ر	ز	س
ش	ص	ض	ط	ظ	ع	غ	ف	ق	ك	ل	م
ن	و	هـ	ي								

ب - الأرقام

٠ ١ ٢ ٣ ٤ ٥ ٦ ٧ ٨ ٩

ج- كل من الفقرتين التاليتين:

الفقرة الأولى:

قالت أعرابية : مسكين العاشق , كل شيء عدوه: هبوب الرياح يقلقه, ولمعان البرق يؤرقه, ورسوم الدار تحرقه, والعذل يؤلمه, والتذكر يسقمه, والبعد ينحله, والقرب يهيجه, والليل يضاعف بلاه, والرقاد يهرب منه, ولقد تداويت بالقرب والبعد فلم ينجح فيه دواء , ولا عزى فيه عزاء ولقد أحسن الذي قال:

ولقد زعموا أن المحب إذا دنا يمل وأن النأي يشفي من الوجد

بكل تداوينا فلم يشفي ما بنا على أن قرب الدار خير من البعد

الفقرة الثانية:

لا يبالغ من يقول أن التمر صديق الصحة , حيث أنه مادة غذائية طبيعية خالية من الإضافات والمواد الحافظة, غني بالألياف والسكريات التي تمتص من قبل الجهاز الهضمي , يستخلص منه عدد كبير من العقاقير والمضادات الحيوية التي يمكن أن تستعمل في الوصفات الطبية , به كثير من الأحماض على سبيل المثال حامض الإسكوريك .

ومن ثم لوحظ أنه يعمل على منع ظهور العديد من الأمراض الخطيرة مثل سرطان الأمعاء الغليظة وسرطان المخ, ويقلل من تشكل الحصى بالمرارة ويمنع تسوس الأسنان و يعالج به لسقوط الشعر ولجفاف الجلد وضعف التركيز وأمراض اللثة وضيق التنفس وحموضة المعدة وخفض نسبة الكوليسترول, مقو للكبد , لذا علينا ألا نسقط التمر من طعامنا يمكن أن تأكله بالزبد أو مع الخبز أو منفردا, فكم هو لذيذ ذلك الغذاء .

Figure 3.1: Sample text form participants

Participants were asked to complete the questionnaire provided, detailing their age, gender, handedness, level of education, nationality and the geographical area they lived in when they were taught to write (Appendix 1). These personal data were entered in Microsoft Excel spreadsheets to prepare a general analysis. The obtained information was recorded for future study such as handedness, differences in the handwriting between male and female and variation in the handwriting of different aged people and so on.

The focus was the nationality of the writers and not age, gender, handedness or education levels as this study was originally designed to test the possibility of identifying the nationality or the region from the handwriting. Factors such as gender (297 females and 303 males), age (255 females and 265 males in the age group of 20 to 49 forming bulk of the samples) and handedness (544 right handed, 45 left handed and 11 being ambidextrous) were briefly considered for analytical purposes. The results obtained from these analysis are presented in chapter 4 for future study requirements. The numbers stated above emphasise that the analyses were being carried out on participants with similar cultural backgrounds.

Ruled papers were given in order to illustrate the relevance of the line of writing to Arabic text, that is the position of written elements and dots in relation to the line. The subjects were instructed to use one side of the given papers for clarity in handwriting and any future study in regard to pen pressure.

In addition, participants were required to complete the survey using a ball point pen, so the samples could be used for further research, for example to study the direction of the stroke and pen pressure. Also, using ball point pen could be of use for a document examiner to assess and to observe the

direction of marks or what are called “striations”. Therefore, in a given ink line made by a ball point pen, it should be possible to determine its direction, provided that striation marks are present. Striation marks thus have a vital role in handwriting analyses (Totty, 1985). Since texts written with ballpoint pens are known to last for a longer period than those using other media of writing ball point pen ink was preferred over other writing tools such as pencils or fountain (ink) pens (Nasser, unpublished). Individuals were also asked to write at their normal speed and whilst they were seated comfortably at a desk (Appendix 2). This was to ensure that the sample was written in the individual's normal handwriting as individual's characteristics and general appearance of the writing are believed to be affected factors, such as the speed of execution, whether is writing quickly or slowly and the posture of the writer (Huber and Headrick, 1999). These were considered important, as the handwriting should be normal, as explained in chapter 1.

3.4 COPYBOOK ANALYSIS

As mentioned earlier in chapter one, copybooks or what is called the “writing system”, officially used by Ministry of Education in the four Arabic countries were obtained and they were visually compared with each other in order to identify any differences in the formation of the Arabic characters. This was necessitated for a clear understanding of the way the Arabic characters are taught to be written in each country. The comparison of the ten characters and one word chosen in this study revealed that the four copybook styles have the same characteristics as is shown in the Table 3.1. Where differences are perceived to exist, they are to be ignored because of the criteria that have been selected as explained later in the chapter for each character form.

Table 3.1: Copybook styles of some Arabic alphabets in the four countries

Character	Character forms in the four Arabic countries			
	Jordan	Morocco	Oman	Tunisia
Thaa				
Jeem				
Thal				
Zai				
Za				
Ghayn				
Kaf				
Meem				
Haa				
Yaa				
Lam Alif				

3.5 ANALYSIS OF SAMPLES

The handwriting samples and questionnaires were numbered before segregation. All six hundred handwriting samples were scanned and stored into digital format (jpeg) to maintain a proper and long lasting record of the samples and to help in the analysis of the handwriting. This also enables the finer details to be enlarged when needed during the analysis as compared to performing the task manually using magnifying glasses.

Ten characters and one word were chosen for the classification purposes; these being Thaa, Jeem, Thal, Zai, Za, Ghayn, Kaf, Meem, Haa, Yaa and the word Lam-Alif which is a combination of two characters, "Lam" (ﻝ) and "Alif" (ا). Out of these, eight are connecting characters and the remaining are unconnected. The selected characters and the word, as explained later in the chapter, are of a fairly complex structural nature that can produce a certain degree of variation and richness in both class and individual features.

The choice of the characters was based on the existence of similarities of certain characters which fall into a group of characters having similar formation and characteristic forms in the way they are written. Some other characters selected were of a type which has no other similar characters.

Numerals, dotting and glottal characters were not included in this study. Since the numerals are not adopted in the Western Arabic Countries included in this study, they have been omitted. Similarly, dotting and glottal characters were also not included due to the fact that they do not change the basic structure of the characters selected for the analysis. The key factors that influenced the selection of the characters were based on: (i) the complexity of the formation of the characters, such as from where the character is started to

be written; (ii) the different parts (upper and lower) that form a character, whether the character is joined to either the previous or following character or joined to both; (iii) the trailing edge of the character; and (iv) whether the character is formed of lines or curves or both. The other major consideration in selecting the characters for the study was the possibility of variations in the way the characters are written, for those characters that fall into groups of similar looking characters and those that are independent by themselves. In all cases, the most complex characters were chosen as structurally simple characters could have much less scope of variability.

3.6 CRITERIA USED FOR HANDWRITING CLASSIFICATION

As mentioned in the previous chapter, Arabic characters have their own characteristics with respect to their formation and structure, hence, all the 600 samples were analysed to identify a number of criteria and finally to arrive at specific criteria in order to ensure that all possible forms of the examined characters are covered. The criteria determined for this study were based on the character formation, starting point, pen movement, method of construction and design as detailed below. This was done by studying all the samples and identifying the various forms written by the participants. These forms were then separated out and the common forms were put under one criterion thus being able to identify multiple criteria for each character in each position for the analyses.

It is worth mentioning that the criteria selected for this study were based on the expert knowledge of the author in Arabic language and not based on any specific standards, as no such standards have been researched or defined so far. In addition, as stated earlier, Arabic handwriting has its own peculiarities

and therefore, the criteria selected for this study are different compared to those applied for other studies such as the study carried out by Turnbull, *et al* (2010) on class characteristics of Polish people writing in English. The study was carried out on class characteristics in the English handwriting of Greek people (Katsaridou, 2009). Another study investigated the class characteristics in English handwriting of the three racial groups in Singapore (Chinese, Malays and Indian) (Cheng, 2005). It was evident that the classification of individual letters presents more difficulties within the cursive handwriting than it does within block handwriting because of the influences of preceding and following letters and the positions of letters within words (Hardcastle and Kemmenoe, 1986).

The following sections describe the various criteria chosen for each character in all the positions considered and the tables in each section present a sample of the character form selected based on its compliance with the criteria. The scoring of the letter forms was based on readily visible and understandable criteria. As the aim of this research was to study variation between individuals and not variation within individual's handwriting, therefore, only one character was scored for each participant. Where there was more than one occurrence of a character that was to be scored in a sample of handwriting, the simplest word, in terms of number of characters, containing the character under study was scored first and other occurrences were checked for consistency with the one scored first.

3.6.1 Character Thaa ث

Thaa is the fourth character in the Arabic alphabets, and is one of the three joined characters; Baa (ب) and Taa (ت), with its distinctive shape along

with three dots. When written as an unconnected character (ث) Thaa generally takes the same basic shape as when it is written at the end of a word (حيث) ,while when written at the start of a word (ثم) Thaa takes the same shape as when it is placed in the middle of a word (كثير).

For the purposes of this study, Thaa - in the four different positions - was divided into three sections, the start of the character as a curve/line/blind stop, the lower section of the character as a line/curve, and the end of the character as a curve/line/blind stop or a combination of these, with and without reversed form. Based on these criteria, 5 different shapes were considered for unconnected, 10 for start, 5 for middle and 6 for the end of the character with each shape being characteristic in regard to its formation and representation.

Table 3.2 shows an example of the criteria selected for each of the four positions out of the 26 criteria that were identified for this character.

Table 3.2: Description of criteria for character Thaa in all four positions

Position	Form	Description of the criteria
Unconnected		Curve at the start and blind stop at the end
Start		Line (only line without any edge at either start or end)
Middle		3 Curves (Curve at the start .middle and at the end)
End		3 Lines (Line at the start, middle and at the end)

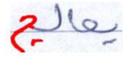
3.6.2 Character Jeem ج

The character Jeem has the same formation in shape to two other characters in the Arabic alphabet called Ha (ح) and Kha (خ). Therefore, observations made in relation to this character can be considered the same for

these other, similar characters. For the purposes of this study, the criteria utilised for character Jeem - in the four different positions – were based on whether they are written as “open” or “closed”. The “open” form was identified when the upper portion of the character was not joined to the curve of its lower portion, while the “closed” form was identified where the upper portion of the character joins the lower portion’s curve. Additionally, the forms used in relation to this character have been identified on the basis of whether or not a backstroke is used, and whether a sharp edge is present or not. Within this study, eight different forms were utilised for this character in each of the four positions (i.e., as an unconnected ج or standalone character, and at the start جـ, middle يج, or end of a word يعالج).

Table 3.3 shows an example of the criteria selected for each of the four positions out of the 24 criteria that were identified for this character.

Table 3.3: Description of criteria for character Jeem in all four positions

Position	Form	Description of the criteria
Unconnected		Closed sharp without backstroke
Start		Open sharp with backstroke
Middle		Closed sharp with backstroke
End		Open curve without backstroke

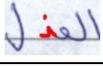
3.6.3 Character Thal ذ

The character Thal has an identical shape to the character Dal (د) in the Arabic alphabet, only being distinguished by a single dot placed at the top of

the character and both are non-connecting characters. For the purposes of identification within the context of this study, the character Thal was divided into two sections, an upper and lower section. This character takes the same shape when written in the middle **إذاع** and at the start **ذلك** of a word as when written as an unconnected or standalone character **ذ**. For this reason, this character was analysed for the unconnected and end positions. The criteria utilised for these two positions of the character were based on the character's formation either as a curve or a line. In total, four different forms were identified among the samples in both positions.

Table 3.4 shows an example of the criteria selected for each of the two positions out of the 8 criteria that were identified for this character.

Table 3.4: Description of criteria for character Thal in all four positions

Position	Form	Description of the criteria
Unconnected		Curve - Curve
Unconnected		Line - Line
End		Curve - Curve
End		Line - Line

3.6.4 Character Zai ذ

The Arabic alphabets consist of two characters; Ra (ر) and Zai (ز) which take on identical shapes, but are distinguished by a dot placed above the main character. Additionally, these two characters are non-connecting characters. The character Zai takes on the same shape **ز** when written as an unconnected character or at the start of the word **زين**. When placed in the middle of a word, **مزيد** it is connected to the preceding character, but not the

following character. Therefore, data were collected only for the unconnected character, which were then considered the same as for the other two positions. When this character is written at the end of a word **الخبز**, it takes on a slightly different form. The criteria utilised for these two positions, namely as unconnected and end of the character, are based on the character's formation either as a curve or a line. In total, four different forms were identified among the data in each position.

Table 3.5 shows an example of the criteria selected for each of the two positions out of the 8 criteria that were identified for this character.

Table 3.5: Description of criteria for character Zai in all four positions

Position	Form	Description of the criteria
Unconnected		Curve at the start
Unconnected		Line
End		Curve at the end
End		Curve

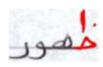
3.6.5 Character Za **ظ**

The two Arabic characters Za (**ظ**) and Ta (**ط**) have identical shapes, the only difference between the two being the dot above the character Za. In its most common form, the shape of the character Za has two components, with the lower portion forming a complete circle, and the upper portion consisting of a straight vertical line. Within the context of this study, only the lower portion of this character has been considered, with the criteria associated with this character being based on whether it is written as a full circle or triangle, which would either be cut at the end or terminated as a whole loop.

In total, six different forms of this character were identified when included as an unconnected character **ظ**, seven different forms were identified when placed at the start of a word **ظهور**, seven different forms were identified in which was included in the middle of a word **الغليظة** and six forms in total were identified in which the character Za was included at the end of a word **لوحظ**.

Table 3.6 shows an example of the criteria selected for each of the four positions out of the 26 criteria that were identified for this character.

Table 3.6: Description of criteria for character Za in all four positions

Position	Form	Description of the criteria
Unconnected		Circle with cutting
Start		Triangle without cutting
Middle		Triangle with cutting
End		Circle without cutting

3.6.6 Character Ghayn غ

The Arabic character Ghayn has identical shape as the character Ayan (ع), only being distinguished by a single dot placed at the top of the character Ghan. This character has two sections, an upper section, written above the line, and a lower section, written below the line when written as an unconnected character **غ** and at the end of a word **يبالغ**. When written at the start of a word **غني** or in the middle **الغناء** of a word, the lower section is not written. Hence, the criteria selected are based on these considerations. In total, four different forms were identified among the samples in both unconnected and start positions and six forms for both of the other positions that is at the middle and end.

Table 3.7 shows an example of the criteria selected for each of the four positions out of the 20 criteria that were identified for this character.

Table 3.7: Description of criteria for character Ghayn in all four positions

Position	Form	Description of the criteria
Unconnected		Curve - Opened curve (the upper part is curve and open and lower part is also curve and open).
Start		Line without line pointing downwards (the upper part is line and lower part not written)
Middle		Round (the upper part is closed with round shape and lower part is not written)
End		Closed with sharp edges – open (the upper part is closed with sharp edges and lower part is open).

3.6.7 Character Kaf ك

The Arabic character Kaf has a characteristic form and takes on different shapes when written as an unconnected character as compared with situations in which this character is written as part of a word. When written as an unconnected character (ك), Kaf takes on a very specific shape that includes a glottal stop as part of the character which is very similar in shape to that of the glottal stop “Hamzah”. Writing this character in the unconnected form is generally done with a single stroke, and requires certain criteria which incorporate the stroke and glottal stop. In order to analyse the samples for the purposes of this study, this character was split into two portions, an upper and lower portion and the criteria selected as a combination of these two along with or without the glottal stop. In all 6 different shapes were identified among all the samples.

When Kaf is written at the start of a word (كاف), for the purposes of this study, this character was split into two components, an upper component and a lower component which connects the upper component with the end of the character. These are classified as combinations of curves and/or lines with the samples analysed to determine whether the two components were connected or unconnected, which signifies whether the character was written in a single stroke or in two separate strokes. In total, 10 forms were identified for situations in which the character Kaf was included at the start of a word.

The criteria used for situations in which the character Kaf was placed in the middle of a word (كافين) were the same as the criteria used when this character was placed at the beginning of a word, as discussed previously. However, only eight forms were utilised in relation to situations in which the character Kaf was placed in the middle of a word.

When placed at the end of a word (كاف), the character Kaf takes on a different shape as compared with when it is written in the middle or at the start of a word. However, when written at the end of a word, this character takes on the same shape as when it is written as an unconnected character. Therefore, the criteria used in order to analyse these samples were the same as when the character Kaf is written as an unconnected character. In total, six different forms were identified in the data.

Table 3.8 shows an example of the criteria selected for each of the four positions out of the 30 criteria that were identified for this character.

Table 3.8: Description of criteria for character Kaf in all four positions

Position	Form	Description of the criteria
Unconnected		Single stroke - curve with glottal stop (GS)
Start		Single stroke - Line Curve Connected
Middle		Double strokes- Line Line unconnected
End		Double strokes- Line Line unconnected without (GS)

3.6.8 Character Meem م

The character Meem generally has two sections, an upper section, written above the line, and a lower section as a vertical line written below the writing line. When written at the beginning of a word (مَن), it is common for only the upper section to be shown. This is also commonly the case when written in the middle of a word (مِج), connecting the preceding and following characters. However, when this character is written at the end of a word (مِمْ), it is written in its full form, which has an ending curve which is normally directed below the line of writing. With regard to this study, the focus in relation to this character was the starting point of the character in regard to how it is written. Regardless of the position of this character, the criteria used for data analysis consisted of whether the character starts from the left, right, up, or down position, and whether it is written in a counterclockwise direction. Five forms in total were utilised for this character when it is unconnected, five for start, six for middle and six for end positions.

Table 3.9 shows an example of the criteria selected for each of the four positions out of the 22 criteria that were identified for this character.

Table 3.9: Description of criteria for character Meem in all four positions

Position	Form	Description of the criteria
Unconnected		Anticlockwise
Start		Start from right
Middle		Start from left
End		Start from down

3.6.9 Character Haa هـ

The Arabic character Haa is unique as the Arabic alphabets do not contain any other character taking on the same shape. In addition, this character is very distinct in that when written as a standalone, unconnected character (هـ), as well as at the start of a word (هـ بوب), it takes similar shapes. This character takes on different shapes when written in either the middle (هـ رپ) or at the end of a word (من هـ). Compared to the other characters focused upon in this study, data collection for the character Haa was conducted differently. Specifically, the focus of the criteria associated with this character's four different positions was based on how the writer begins to write this character, as opposed to dividing this character into multiple parts. This is one of the more unusual characters in the Arabic alphabet as there is little resemblance between its multiple forms.

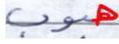
When written at the start of a word, the character Haa takes the same shape as when written as a standalone character. The criterion that was utilised to analyse the data for this character in a stand alone position was also used here which was the starting point.

When written in the middle of a word, the character Haa takes on a different shape and can be written in multiple ways. The shape of this character when written in this position, along with the starting point, was found to vary very widely between writers in the same country as well as between various regions. The criteria used for this character in relation to this position were based on how the writer begins to write this character, and the position of the two circles which compose a portion of this character and their relation to each other.

Finally, the character Haa takes on a completely different form when written at the end of a word. The criteria used in relation to this position were based on how this character was written (as a line with a circle or triangle) and whether it was written in a clockwise or counterclockwise direction. In total, five different forms were identified for unconnected, four for start, eleven for middle and eight for the end position.

Table 3.10 shows an example of the criteria selected for each of the four positions out of the 28 criteria that were identified for this character.

Table 3.10: Description of criteria for character Haa in all four positions

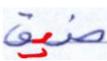
Position	Form	Description of the criteria
Unconnected		Start from Left
Start		Start from down Moving upwards
Middle		Start from right and two circles one over the other (Up)
End		Anticlockwise with a triangle without a line

3.6.10 Character Yaa ي

The Arabic character Yaa has a unique form, with no other Arabic characters taking the same shape. This character is also distinct in that when written as an unconnected character (ي) and at the end of a word (يشفي), it takes on similar shapes. It also takes on similar shapes when written at the start (يقول) or in the middle of a word (ضيق). The criteria used for the four positions identified are based on how the writer starts to write the character and the formation used at the start of the character. For instance whether the writer starts writing the character with a curve or a line and whether the line is pointing out to the right, left, or upward and how the writer executes the character, with or without a long end.

In total four different forms were utilised for this character when written in each of the four positions. Table 3.11 shows an example of the criteria selected for each of the four positions out of the 16 criteria that were identified for this character.

Table 3.11: Description of criteria for character Yaa in all four positions

Position	Form	Description of the criteria
Unconnected		Start with a curve and long end
Start		Start with a line to left
Middle		Start with a line to right
End		Start with a curve and curve joining edge

3.6.11 The word Lam Alif لآ

The word Lam Alif consists of a combination of two characters, “Lam” (ل) and “Alif” (ا). While the character Lam consists of a connecting character, the character Alif is a non-connecting character, meaning that it cannot be connected to a following letter. This word is written such that the character Alif cuts into the character Lam. Additionally, Lam Alif is considered a stand alone word, as opposed to a single character. It takes the same shape regardless of where it is written. Within this study, six different forms have been identified with relation to this word. The criteria used for this study are based on how the writer starts to write the word, whether in one or two strokes, and whether Alif cuts into the character Lam and whether forming a circle or triangle.

Table 3.12 shows an example of the criteria selected for this word out of the 6 criteria that were identified.

Table 3.12: Description of criteria for the word Lam Alif

Position	Form	Description of the criteria
Standalone		One stroke + cross with a circle (Alif cutting across Lam written in a single stroke forming a circle shape)
		One stroke + cross with triangle (Alif cutting across Lam written in a single stroke forming a triangle shape)
		2 strokes + cross with curve (two strokes and a cross of the characters with a curve).
		Two strokes without a cross with a vertical line.

The handwriting samples were examined for the various selected criteria by using a hand lens and by enlarging the scanned samples on the computer, in order to obtain a clear image of the class characteristics of handwriting and

thereby to ensure that the character forms are classified into the right criteria. The findings were classified into a number of common styles or forms based on the printed copybook styles used in the four Arabic countries, as stated above in section 3.4. They were then grouped for the purpose of commonality and classified in forms relevant to their formation, pen movement, method of construction and design in order to proceed with the comparison between the writers of each country. The results were recorded in numerical tables.

3.7 STATISTICAL ANALYSIS OF CLASS CHARACTERISTICS

The collected findings were statistically analysed and different statistical approaches such as association test with chi-squared statistic, correspondence analysis with analysis of similarity (ANOSIM) and tree analysis were adopted for this purpose. These approaches were used because they were appropriate for the type of data collected for the study, the data being predominately multinomial category variables. These tests were applied to show the relationship, if any, between the handwriting and nationality and/or region of the writer, the differences between the handwriting of the subjects in the four countries chosen for the study and to determine whether or not the four countries differ significantly from each other. Also, 100 samples used in this study and 80 samples that are not used in the study were tested blind based on the tree analysis.

The results obtained from these tests were illustrated in tables, plots and graphs. The tests used are briefly described as follows.

3.7.1 Association test

An association test is a simple tool that can be used to test if there is an association between two variables. In this study, association test has been applied to show whether the character forms extracted from the handwriting samples and the country of the writer could be associated.

This test produces a plot with two colours; black and red. The black rectangles represent a positive association, whereas, red rectangles show negative associations. In this plot the larger (in area) the black rectangle, the more positive the association and hence the individual associations are strongest. In this case, if the p-value is less than 0.05, then it indicates a statistically significant association between the country and the character forms. A p-value of greater than 0.05 would suggest no statistically significant association. The significance of association is tested by the chi-square statistic. The chi-squared test in conjunction with an association plot shows any relationship between character type and country.

3.7.2 Correspondence analysis (CA)

Originally devised by Hirschfeld (1935), correspondence analysis, or reciprocal averaging, is a method of ordination, where the goal is to represent similarity of samples by their proximity on a plot. The dissimilarity is derived from one of several methods, the Bray-Curtis method being used in the analysis here (Hirschfeld, 1935).

Correspondence analysis (CA) is a multivariate statistical technique in which all data should be non-negative and the rows and columns are treated equivalently. Since CA is an inferential technique it was used since the tables

were far too large to produce a meaningful association test and also the cell value being 1 or 0, it rules out using chi-squared statistic.

Correspondence analysis was used for this research as it gives a graphical representation of all handwriting samples in relation to each other (the closer they are plotted the more similar), as well as in relation to the character forms. The produced graph based upon all character forms, with handwriting samples grouped by country, is useful to show how similar samples are and how much variation there is within and between groups.

3.7.3 ANOSIM (Analysis of Similarity)

ANOSIM is a method devised by Clarke and Green. It compares within-group and among-group dissimilarities (based upon ranks from a dissimilarity matrix) for the original data, with those where group membership is randomly reallocated. The statistic R can range between -1 and +1, and positive values reflect real grouping, the significance of which is provided by the probability derived from a randomisation procedure (Greenacre and Nenadic, 2010).

The analysis of similarity effectively compares the variation within groups to variation between groups to assess whether the groups can be considered distinct (based upon all character forms). The main purpose of applying this technique is to show whether different countries produce individuals who write differently.

3.7.4 Tree test

Tree-based analysis was introduced to statistics by Breiman *et al* (1984). It can be used for both quantitative and qualitative data. For qualitative data, the tree model will produce a classification based upon repeatedly

splitting individuals (handwriting samples) based upon the attributes (character forms) which most effectively and parsimoniously divide the group.

Tree analysis was used in this study, since it attempted to divide a group or any other variable such as age and gender into two by the most discriminating method. It continued to divide groups into two until 'individuals' could not be discriminated any further. This analysis produced a diagram that showed the best way of splitting up all samples into nationality groups. Thus it was a way to divide the handwriting samples repeatedly into groups of countries and hence, classifying the handwriting samples into countries, based upon character forms. It was hierarchical and would choose the most distinct character form first, which was most divisive between countries and then could be used to create a classification scheme for character forms.

3.7.5 Blind tests

Blind analysis strategies, designed to minimise the possibility of bias in experimental results, have become increasingly popular for higher standards of analyses in recent years. Blind test can be defined as “Applied to a test or experiment conducted by one person on another in which information about the test that may lead to bias in the results is concealed from both the tester and the subject until after the test is made” (Heinrich, 2003).

Blind test is the method that can be used to verify whether the criteria selected (classification system) to classify the handwriting samples are proper and accurate and hence to test out the possibility of identifying the nationality or the region in which the writer was taught to write.

Blind test was carried out on 80 fresh handwriting samples (20 samples from each of the four countries) and 100 samples which were used in the study. These were segregated independently and mixed by a person other than the author. Next, the diagram produced by tree analysis, which was based on the handwriting sample analysed for this study, was applied on those samples. The results obtained were recorded and explained in the results chapter.

3.8 UNCLASSIFIED FORMS

If the form of the character in any sample could not be classified to any of the relevant criteria, it was recorded as unclassified and not included in the analysis.

CHAPTER 4

RESULTS

This chapter presents and interprets the results of the descriptive and inferential statistics conducted for this study. Four statistical approaches; association test, the correspondence analysis, ANOSIM and tree analysis along with a series of descriptive statistical analyses, were used for analysing the handwriting samples.

4.1 PARTICIPANTS

Figures 4.1, 4.2, 4.3 and 4.4 present a summary of the demographic data collected on this sample of participants. A total of 600 participants, 150 from each country (Jordan, Morocco, Oman, and Tunisia) comprising of 50.5% males and 49.5% females (figure 4.1) between the ages of 18 and 69 (Figure 4.2) were considered for the analyses. Nearly 91% were right-handed (Figure 4.3). More than 90% of them had completed secondary school and over 43% had additional education beyond a diploma (Figure 4.4).

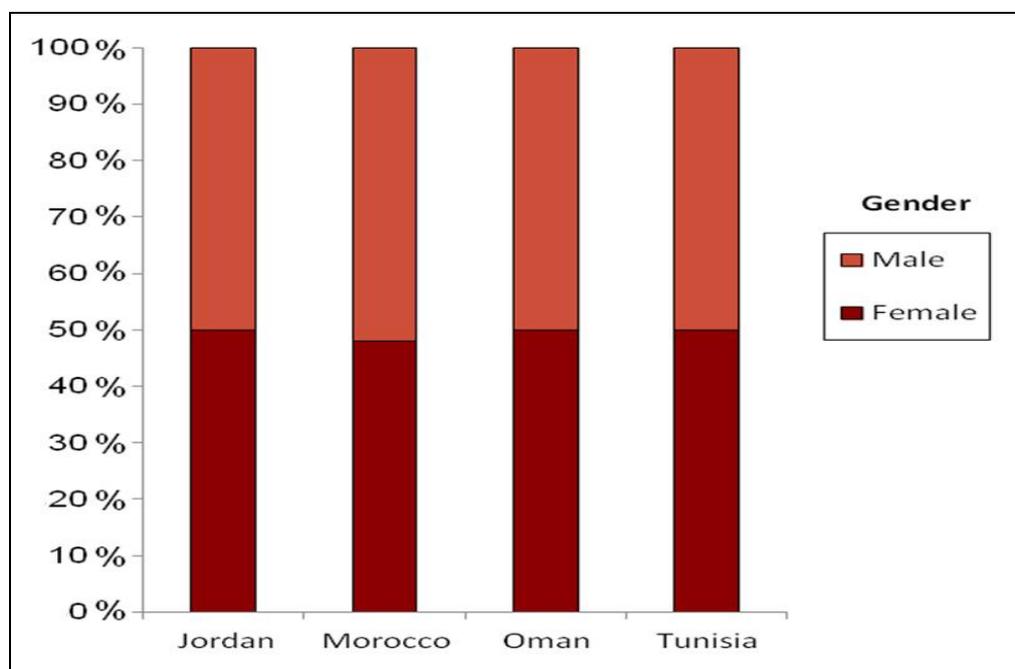


Figure 4.1: Gender distribution amongst countries (by percentage)

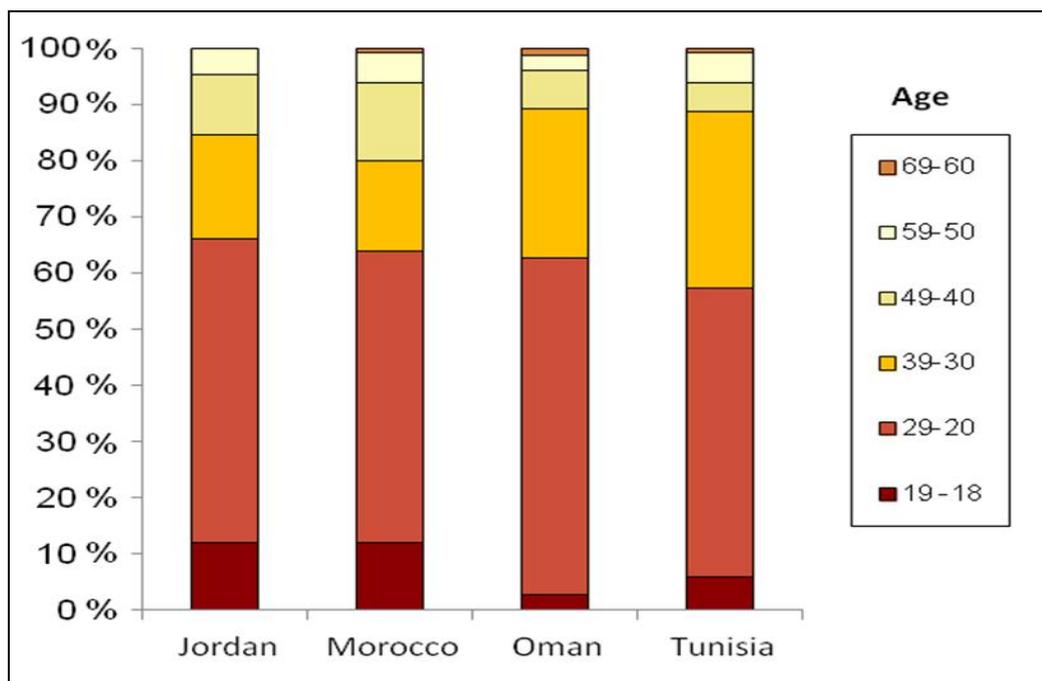


Figure 4.2: Age distribution amongst countries (by percentage)

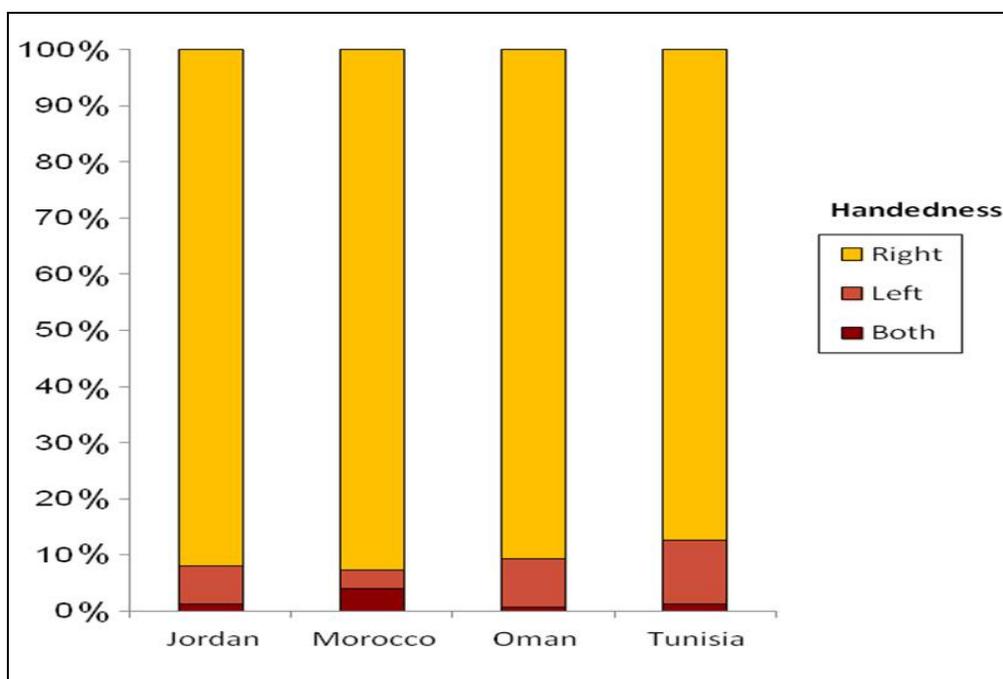


Figure 4.3: Handedness distribution amongst countries (by percentage)

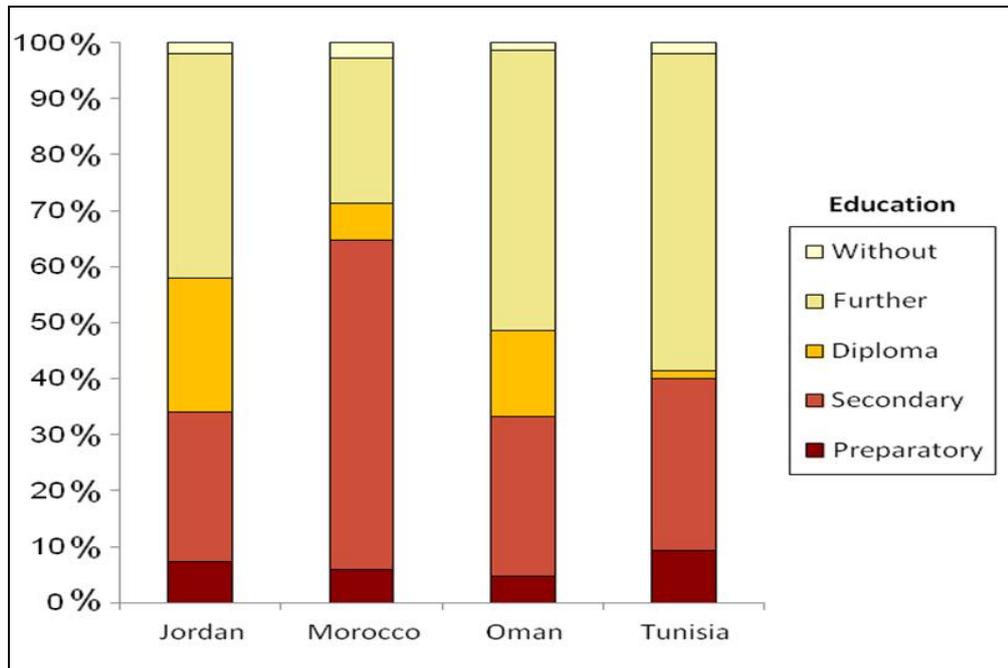


Figure 4.4: Education distribution amongst countries (by percentage)

Table 4.1: The character forms and their associated positions from the handwriting data

Character	Shape	Number of forms				Total
		Unconnected (U)	Start (S)	Middle (M)	End (E)	
Thaa (Th)	ث	5	10	5	6	26
Jeem (J)	ج	8	8	8	7	31
Thal (Tl)	ذ	4	-	-	4	8
Zai (Zi)	ز	4	-	-	4	8
Za (Z)	ظ	6	7	7	6	26
Ghayn (G)	غ	4	4	6	6	20
Kaf (K)	ك	6	10	8	6	30
Meem (M)	م	5	5	6	6	22
Haa (H)	هـ	5	4	11	8	28
Yaa (Y)	ي	4	4	4	4	16
Lam Alif (LA)	لا	6				6
Total						221

4.2 THE EXTRACTED CHARACTER FORMS (CLASS CHARACTERISTICS)

Detailed examination of the all 600 Arabic handwriting samples was carried out in this study. Ten characters and one word were chosen. A total of 221 character forms (class characteristics) were identified. Table 4.1 presents the characters used in this study and the number of character forms associated with each character in each position. The letters within brackets adjacent to each character indicate the abbreviation used in this thesis and the letters (U), (S), (M) and (E) indicate the position.

4.3 STATISTICAL RESULTS

The results obtained from the statistical analyses; association test with chi-squared test, correspondence analysis, ANOSIM, tree test and blind tests, are described in detail in the following sections along with tables and figures that relate to the specific result of each finding. These tests were carried out with nationality as the main variable. The results of tests carried out with other variables, such as, gender, education, handedness and a combination of these with nationality are also tabulated in this section.

4.3.1 Association test

The results presented below are based on the association tests carried out on all the samples. They illustrate whether any association was present between the character forms extracted from the handwriting data and the region or nationality of the writer through an association plot for each character form for all positions (Cohen, 1980). The positive associations are represented by black rectangles and the negative by red rectangles. The area of the rectangle represents the magnitude of the association, whether positive or negative. The

significance of the association is tested by the chi-squared statistic. A resulting p-value of less than 0.05 rejects the null hypothesis: “there is no association between two variables”, in this case the handwriting data and nationality of the writer. The percentages indicated in the plots represent the percentage of samples which used the specific form in each country for the position under consideration.

The results obtained from the chi-squared test conducted in relation to the association tests are presented in Table 4.2. The p-value is less than 0.001 in every case which indicate significant differences between regions and nationality for all ten characters and one word included in this study.

Table 4.2: The results of the associated chi-squared tests with x^2 values ($p < 0.001$ in every case and degrees of freedom are given in brackets)

Character	Position / x^2							
	Un-connected	x^2 (df)	Start	x^2 (df)	Middle	x^2 (df)	End	x^2 (df)
Tha (Th)	ث	49.5 (12)	ث	117 (27)	ث	97.0 (12)	ث	44.0 (15)
Jeem (J)	ج	103 (21)	ج	206 (21)	ج	157 (21)	ج	148 (18)
Thal (TI)	ذ	88.1(9)	-	-	-	-	ذ	144 (9)
Zai (Zi)	ز	214 (9)	-	-	-	-	ز	57.2 (9)
Za (Z)	ظ	68.4 (15)	ظ	112 (18)	ظ	77.5 (18)	ظ	178 (15)
Ghayn (G)	غ	107(9)	غ	25.1 (9)	غ	57.7 (15)	غ	64.2(15)
Kaf (K)	ك	158 (15)	ك	106(27)	ك	80.3 (21)	ك	234 (15)
Meem(M)	م	121 (12)	م	181 (12)	م	280 (15)	م	216 (15)
Haa (H)	ه	223 (12)	ه	241 (9)	ه	473 (30)	ه	123 (21)
Yaa (Y)	ي	238 (9)	ي	8.56 (9)	ي	70.2 (9)	ي	61.2 (9)
Lam Alif (LA)	لا							393 (15)

This leads to the assumption that there are clear differences between the countries for each character and there exist differences between regions; eastern region (i.e. Jordan and Oman) and western region (i.e. Morocco and Tunisia), for each form of each character. This assumption is verified in the following sections in the analysis of each character.

A. Character Thaa (Th) ث

Thaa is the fourth character in the Arabic alphabet, and is one of the three characters with its distinctive shape along with three dots. For the purpose of the study, this character was divided into two parts, the horizontal part, as a curve or a line, and the edges, which appear at either or both ends of the character.

Initially, analysis of the handwriting samples identified five different forms of this character when written unconnected as shown in Table 4.3.

Table 4.3: Character forms of Thaa as unconnected.

Form	Shape	Description
ThU1		Curve – Curve at both ends
ThU2		Line – Line at both ends
ThU3		One edge (Right)
ThU4		One edge (Left)
ThU5		Without edges

Figure 4.5 shows the association of this character when written as unconnected and can be used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 2 was predominant), or from Morocco (where form 4 was predominant) or from Tunisia (where form 3 was predominant).

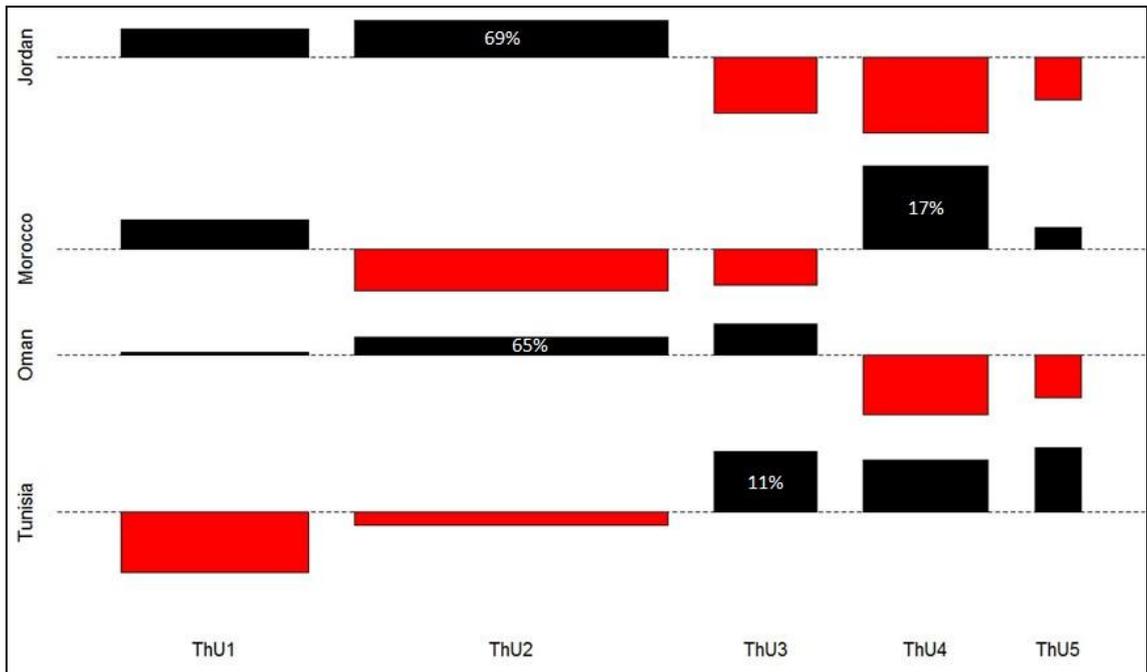


Figure 4.5: An association plot of the character Thaa as unconnected. In this and subsequent figures in this chapters of the thesis, the horizontal bars represent the total number of participants from the four countries who executed the related character form, where as the vertical bars represent the total number of each country.

Table 4.4 shows the actual shapes of the most associated character forms.

Table 4.4: Actual letter shapes of Thaa unconnected

Country	Form	Actual Shape
Jordan	ThU2	
Morocco	THU4	
Oman	ThU2	
Tunisia	ThU3	

Next, when this character is written at the start of the word, it takes a different shape as compared to when written as unconnected or at the end of a word. Ten different forms were identified during the initially analysis of the handwriting samples. These are shown in Table 4.5.

Table 4.5: Character forms of character Thaa at the start.

Form	Shape	Description
ThS1		Line without edge
ThS2		Curve without edge
ThS3		Line with one edge (Right)
ThS4		Line with one edge (Left)
ThS5		Curve with one edge
ThS6		Line with two edges
ThS7		Curve with two edges
ThS8		Reversed Curve
ThS9		Reversed Line
ThS10		Deep curve at start

Figure 4.6 shows the association of this character when written at the start of a word. This shows that this character when written at the start can be used to indicate that a writer was from Jordan (where form 3 was predominant), from the Western Region (i.e. Morocco or Tunisia where form 5 was predominant) or from Oman (where form 1 was predominant).

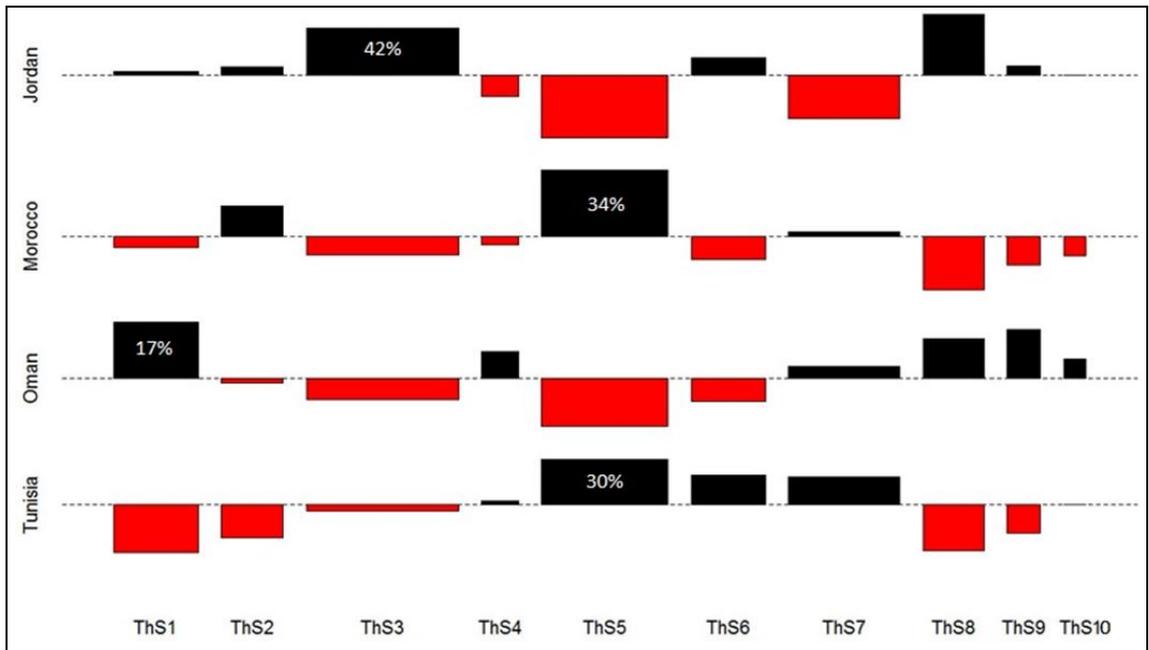


Figure 4.6: An association plot of the character Thaa at the start

Table 4.6 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.6: Actual letter shapes of character Thaa at the start

Country	Form	Actual Shape
Jordan	ThS3	
Morocco	ThS5	
Oman	ThS1	
Tunisia	ThS5	

When this character is written in the middle of a word, it takes the same shape as when written at the beginning of a word and is normally joined to both the previous and the next character in a word. Initially, analysis of the handwriting samples identified five different forms of this character when written in the middle as shown in Table 4.7.

Table 4.7: Character forms of character Thaa in the middle

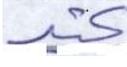
Form	Shape	Description
ThM1		Line with one edge (l)
ThM2		Curve with two edges
ThM3		Line with two edges
ThM4		Line with one (r)
ThM5		Line without edge

Figure 4.7 shows the association of this character when written at the middle of a word and shows that this character can be used to indicate that a writer was from Jordan (where form 1 was predominant), from Morocco (where form 4 was predominant), from Oman (where form 2 was predominant) or from Tunisia (where form 3 was predominant).

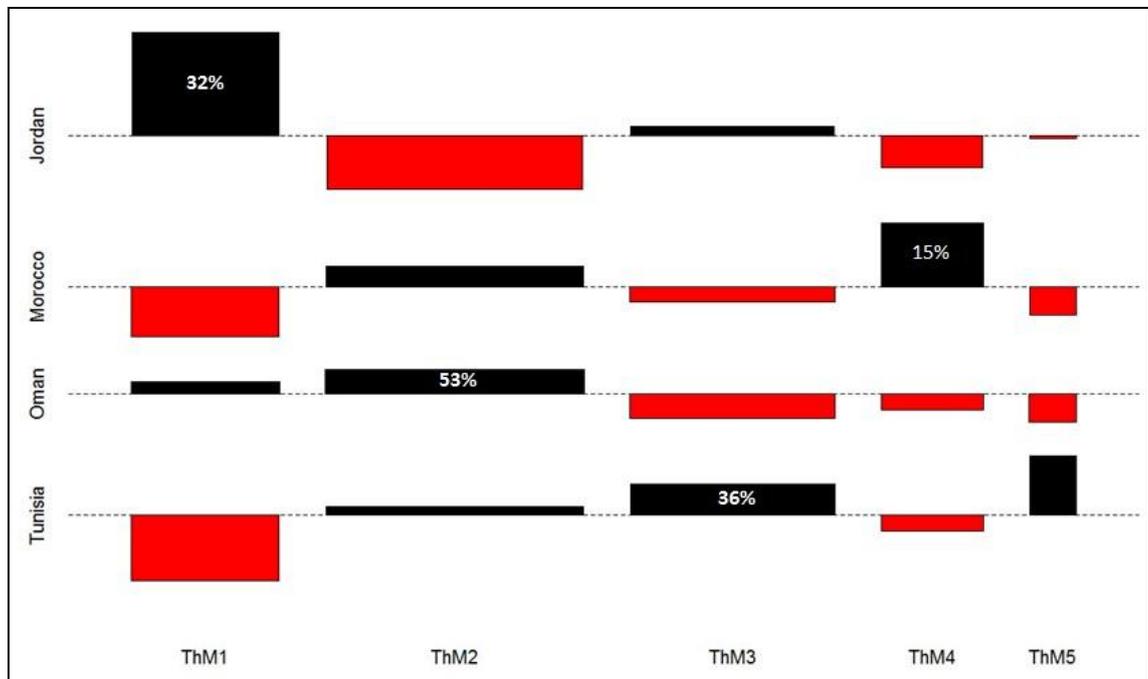
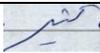
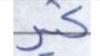
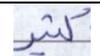
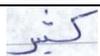


Figure 4.7: An association plot of the character Thaa in the middle.

Table 4.8 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.8: Actual letter shapes of character Thaa in the middle

Country	Form	Actual Shape
Jordan	ThM1	
Morocco	ThM4	
Oman	ThM2	
Tunisia	ThM3	

Finally, when the character Thaa is written at the end of a word, initially analysis of the handwriting samples identified six different forms of this character. These are described in Table 4.9.

Table 4.9: Character forms of character Thaa at the end

Form	Shape	Description
ThE1		Line with one edge (Left)
ThE2		Curve with two edges
ThE3		Line Curve Line
ThE4		Curve with one edge
ThE5		Line with two edges
ThE6		Line with one edge (Right)

Figure 4.8 shows the association of this character when written at the end. This shows that this character when written at the end can be used to indicate that a writer was from Jordan (where form 3 was predominant), from either Morocco or Oman (where form 4 was predominant) or from Tunisia (where form 1 was predominant).

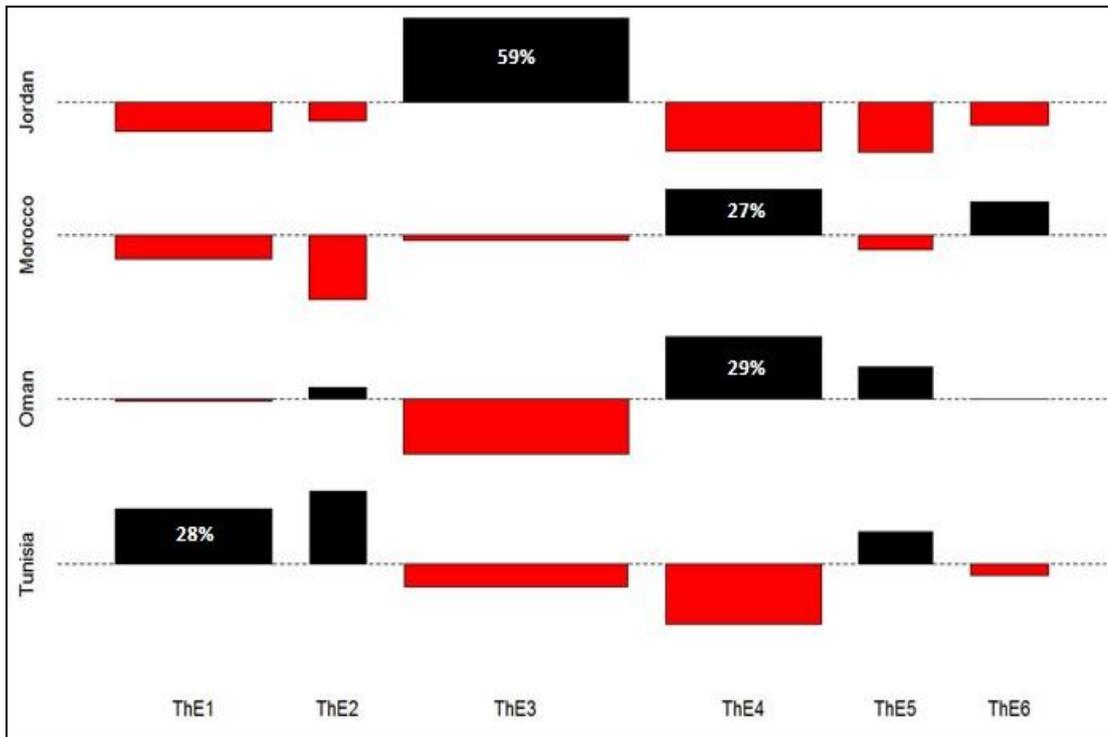
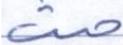
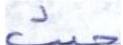


Figure 4.8: An association plot of the character Thaa at the end

Table 4.10 shows some of the handwriting examples with the actual shapes.

Table 4.10: Actual letter shapes of the character Thaa at the end

Country	Form	Actual Shape
Jordan	ThE3	
Morocco	ThE4	
Oman	ThE4	
Tunisia	ThE1	

B. Character Jeem (J) ج

For the purpose of the study, character Jeem was categorised as “open” or “closed” on the basis of whether the upper portion of this character was found to join the lower curve of this character. In regard to this character, the “open” form was identified when the upper portion of the character was not joined to the curve of its lower portion, while the “closed” form was identified in situations

where the upper portion of the character does join the lower portion's curve. Additionally, the forms used in relation to this character have been identified on the basis of whether or not a backstroke is used, and whether a sharp edge is present or not.

Initially, analysis of the handwriting samples identified eight different forms of this character when written unconnected, at the start and middle and seven different forms when written at the end of a word as shown in Table 4.11.

Table 4.11: Character forms of character Jeem in different positions

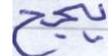
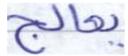
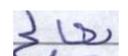
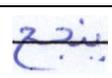
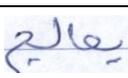
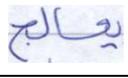
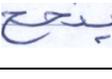
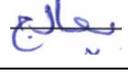
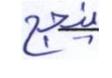
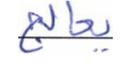
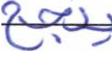
Form No.	Shape of the character forms in different positions				Description
	Unconnected (JU)	Start (JS)	Middle (JM)	End (JE)	
1					Open sharp with backstroke
2					Open sharp without backstroke
3					Open curve
4					Open circled
5					Closed sharp with backstroke
6					Closed sharp without backstroke
7					Closed curved
8				does not exist x	Closed Circled

Figure 4.9 shows the association of this character when written as unconnected and shows that this character when written as unconnected can be used to indicate that a writer was from Jordan (where form 7 was predominant), from Morocco (where form 4 was predominant), from Oman (where form 1 was predominant) or from Tunisia (where form 2 was predominant).

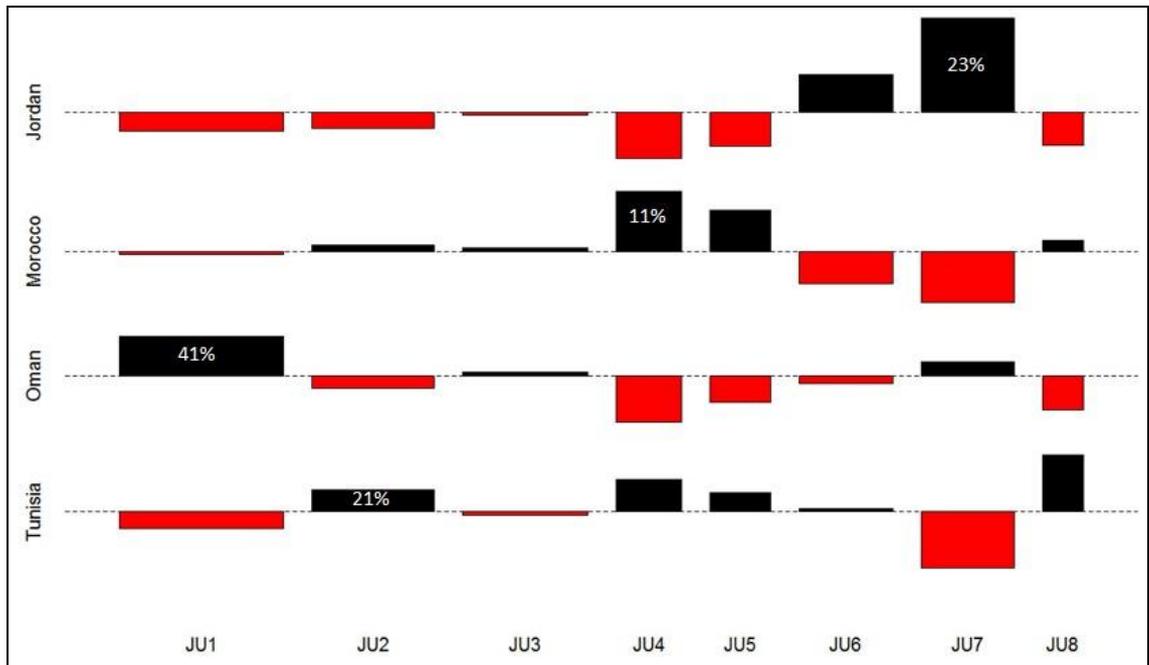


Figure 4.9: An association plot of the character Jeem as unconnected

Table 4.12 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.12: Actual letter shapes of the character Jeem as unconnected

Country	Form	Actual Shape
Jordan	JU7	
Morocco	JU4	
Oman	JU1	
Tunisia	JU2	

Figure 4.10 shows the association of this character when written at start and shows that this character when written at the start of the word can be used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 7 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 2 was predominant).

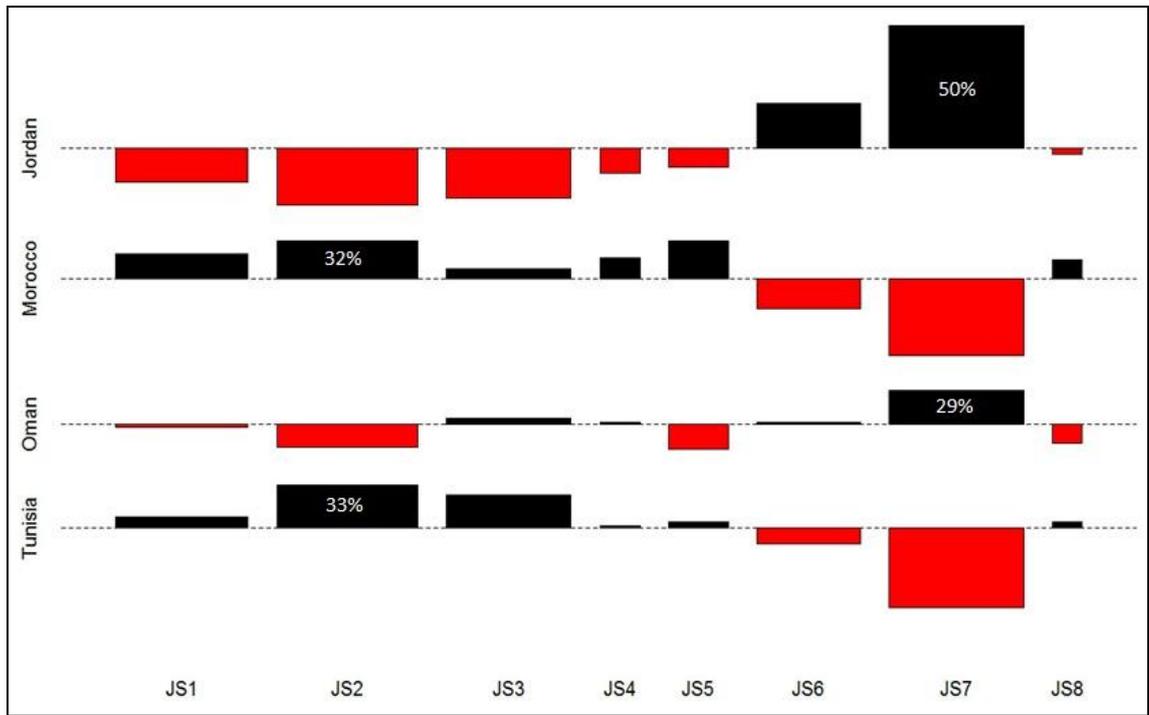


Figure 4.10: An association plot of the character Jeem at the start

Table 4.13 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.13: Actual letter shapes of the character Jeem at the start

Country	Form	Actual Shape
Jordan	JS7	
Morocco	JS2	
Oman	JS7	
Tunisia	JS2	

Figure 4.11 shows the association of this character when written in middle and that this character when written in the middle can be used to indicate that a writer was from Jordan (where form 2 was predominant), from

Morocco (where form 4 was predominant), from Oman (where form 1 was predominant) or from Tunisia (where form 5 was predominant).

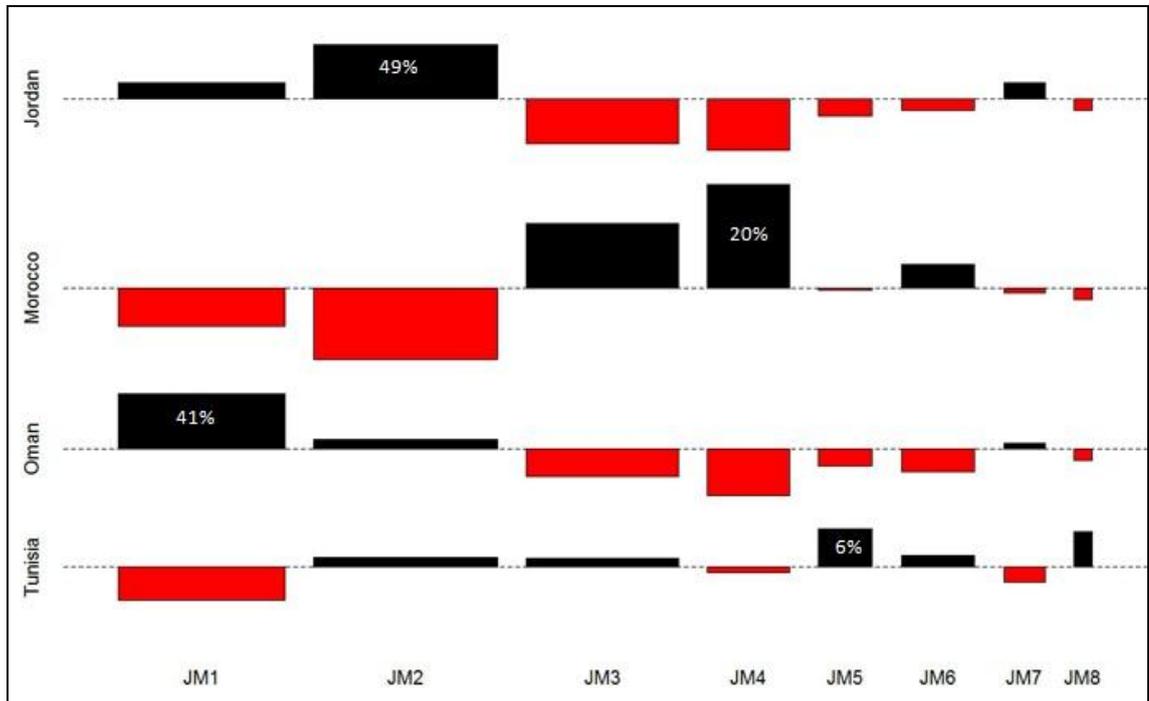


Figure 4.11: An association plot of the character Jeem in the middle

Table 4.14 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.14: Actual letter shapes of the character Jeem in the middle

Country	Form	Actual Shape
Jordan	JM2	
Morocco	JM4	
Oman	JM1	
Tunisia	JM5	

Figure 4.12 shows the association of this character when written at the end and that can be used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 2 was predominant), from Morocco

(where form 4 was predominant) or from Tunisia (where form 3 was predominant).

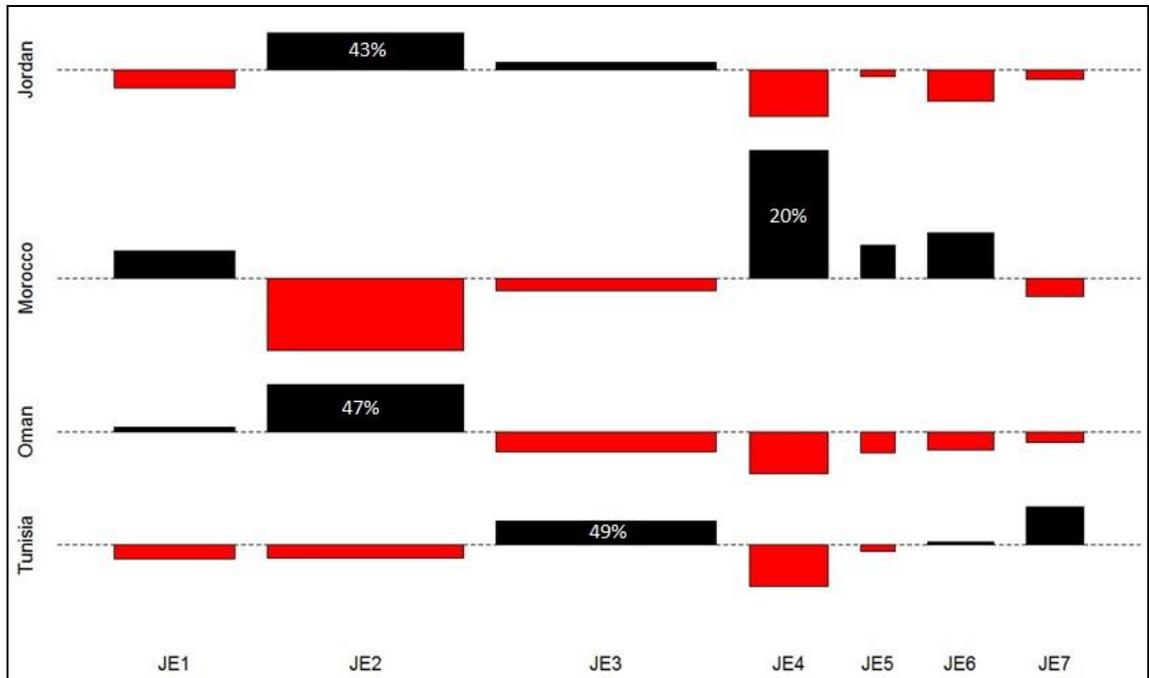
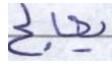
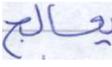
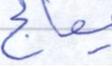
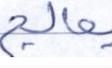


Figure 4.12: An association plot of the character Jeem at the end.

Table 4.15 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.15: Actual letter shapes of the character Jeem at the end

Country	Form	Actual Shape
Jordan	JE2	
Morocco	JE4	
Oman	JE2	
Tunisia	JE3	

C. Character Thal (ث) ذ

Character Thal is one of six characters in the Arabic alphabet that is connected to the preceding character, but not the following character and also takes on the same shape when written as an unconnected character, at the start and middle of the word. Therefore, it was analysed only for the unconnected character, which will be considered the same as the other two positions. When this character is written at the end of a word, however, it takes on a slightly different form. For the purposes of identification within the context of this study, this character was divided into two sections, an upper section which is either curve or line and lower section which is also curve or line with a small line in the left.

Initially, analysis of the handwriting samples identified four different forms of this character when written unconnected or at the end of a word as shown in Table 4.16.

Table 4.16: Character forms of character Thal in different positions

Shape of the character forms in different positions				Description
Unconnected (TIU)		End (TIE)		
TIU1		TIE1		Curve
TIU2		TIE3		Line - Line
TIU3		TIE2		Line with a small Line in the left
TIU4		TIE4		Curve Up

Figure 4.13 shows the association of this character when written as unconnected and that this character when written as unconnected can be used to indicate that a writer was from Jordan (where form 2 was predominant), from either Morocco or Oman (where form 1 was predominant) or from Tunisia (where form 3 was predominant).

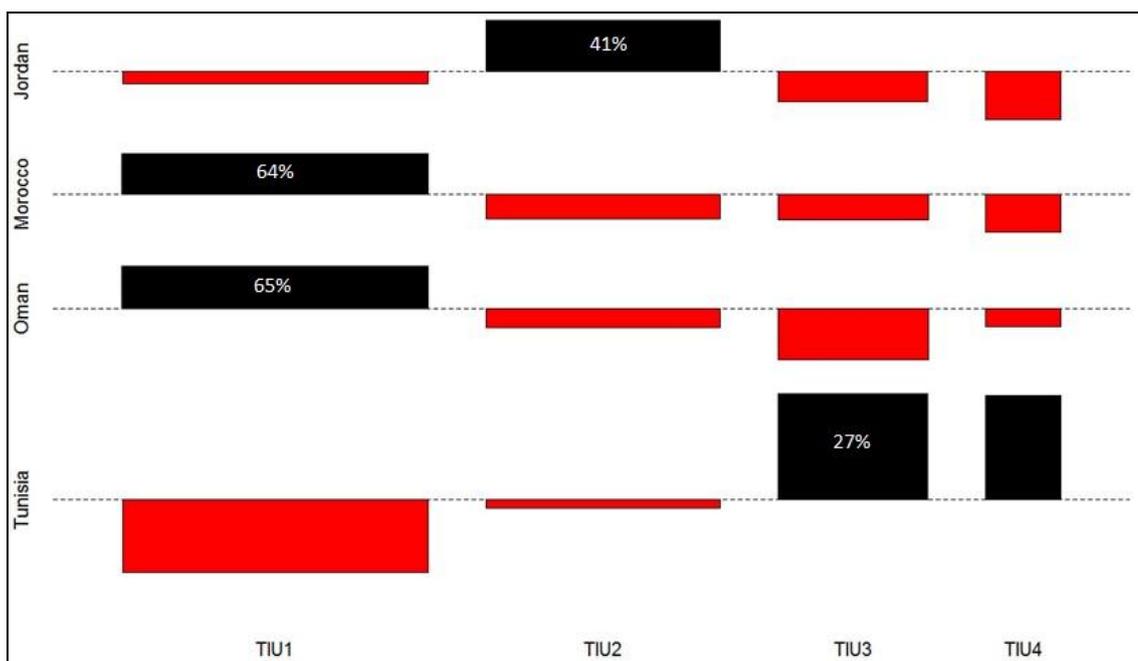


Figure 4.13: An association plot of the character Thal as unconnected.

Table 4.17 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.17: Actual letter shapes of the character Thal as unconnected

Country	Form	Actual Shape
Jordan	TIU2	
Morocco	TIU1	
Oman	TIU1	
Tunisia	TIU3	

Figure 4.14 shows the association of this character when written at the end of a word and shows that this character when written at the end can be

used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 3 was predominant), from Morocco (where form 1 was predominant) or from Tunisia (where form 4 was predominant).

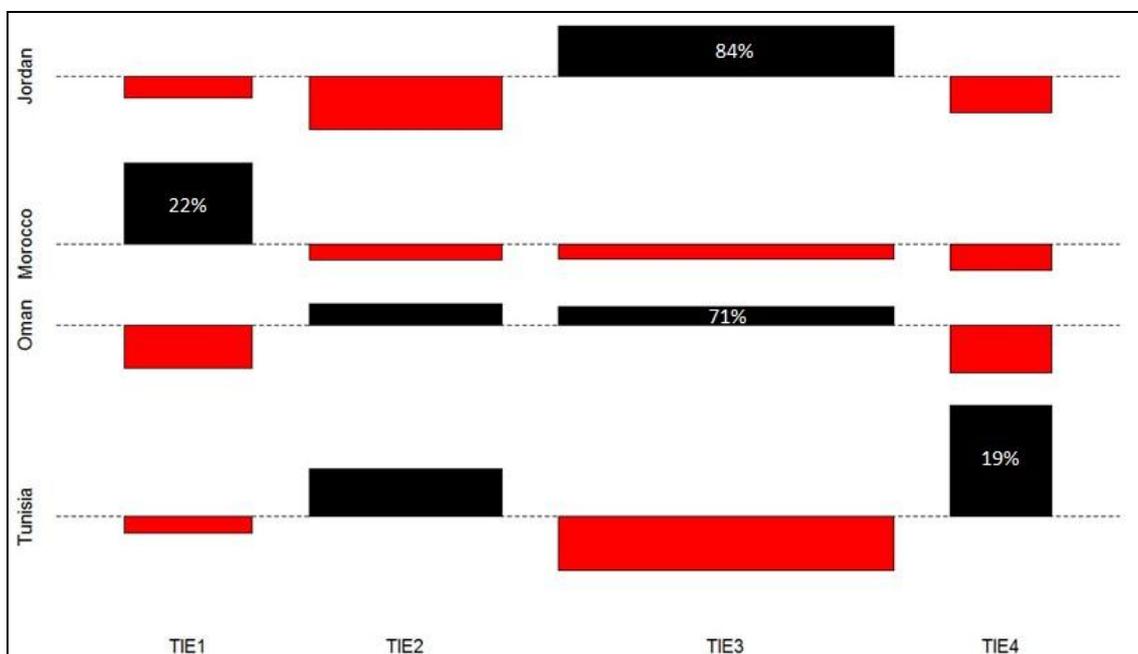


Figure 4.14: An association plot of the character Thal at the end

Table 4.18 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.18: Actual letter shapes of the character Thal at the end

Country	Form	Actual Shape
Jordan	TIE3	
Morocco	TIE1	
Oman	TIE3	
Tunisia	TIE4	

D. Character Zai (Zi) ز

As was the case with the character 'Thal', this character connects to the preceding character, but not the following character and also takes on the same shape when written as an unconnected character, at the start and middle of the

word. Therefore, it was analysed only for the unconnected character, which was considered the same as the other two positions. When this character is written at the end of a word, however, it takes on a slightly different form.

Initially, analysis of the handwriting samples identified four different forms of this character when written either as unconnected or at the end of a word. The criteria utilised for these two positions of the character are based on the character's formation either as a curve or a line as shown in Table 4.19.

Table 4.19: Character forms of character Zai in different positions.

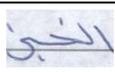
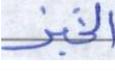
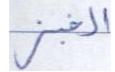
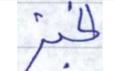
Form No.	Shape of the character forms in different positions		Description
	Unconnected (ZiU)	End (ZiE)	
1			Curve
2			Curve at the start
3			Curve at the end
4			Line

Figure 4.15 shows the association of this character when written as unconnected and that this character when written as unconnected can be used to indicate that a writer was from Jordan (where form 4 was predominant), from Morocco (where form 3 was predominant), from Oman (where form 2 was predominant) or from Tunisia (where form 1 was predominant).

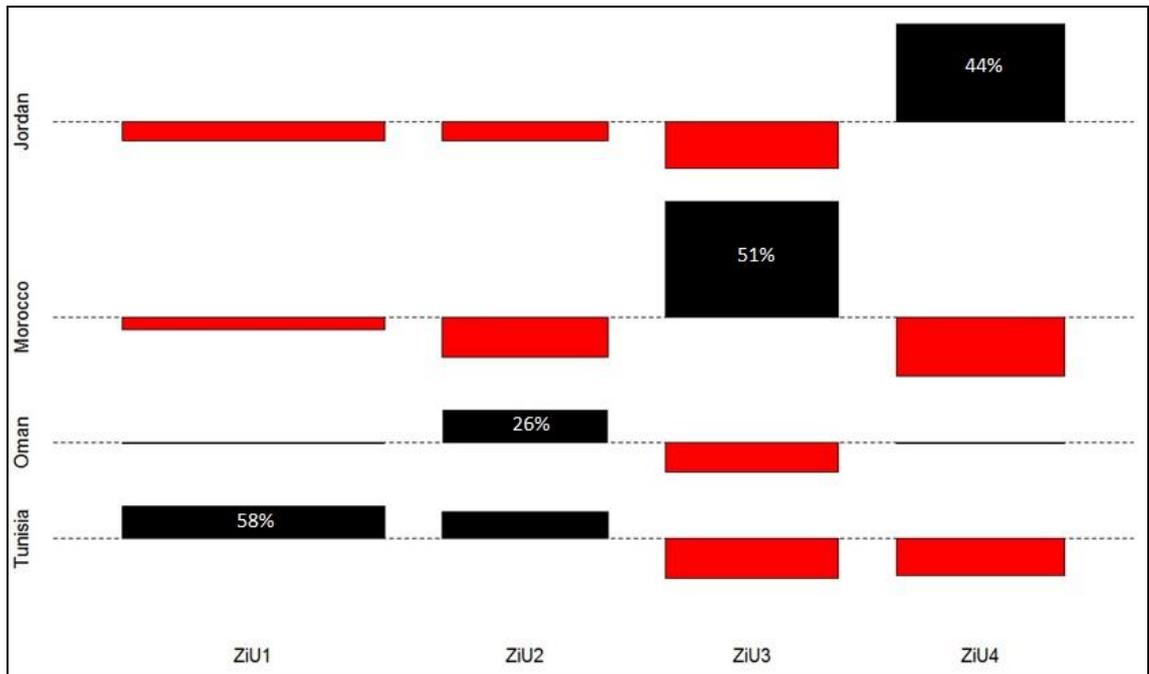


Figure 4.15: An association plot of the character Zai as unconnected.

Table 4.20 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.20: Actual letter shapes of the character Zai as unconnected

Country	Form	Actual Shape
Jordan	ZiU4	
Morocco	ZiU3	
Oman	ZiU2	
Tunisia	ZiU1	

Figure 4.16 shows the association of this character when written at the end and that this character when written at the end can be used to indicate that a writer was from Jordan (where form 2 was predominant), from Morocco (where form 3 was predominant) or from Oman or Tunisia (where form 1 was predominant).

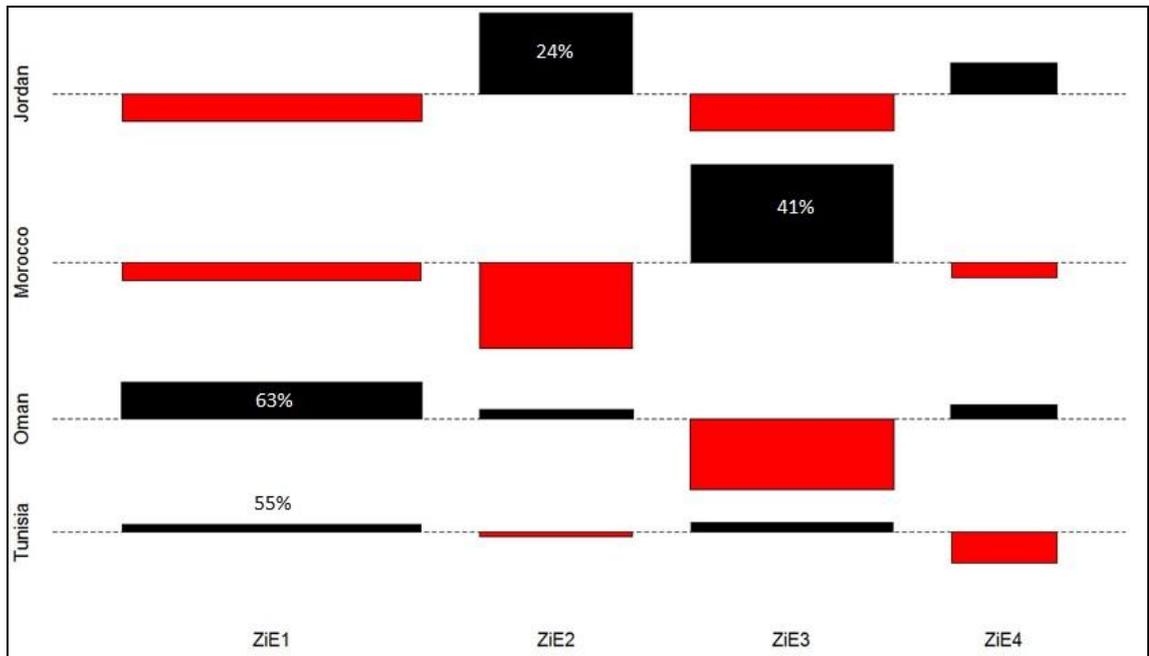
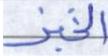


Figure 4.16: An association plot of the character Zai at the end

Table 4.21 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.21: Actual letter shapes of the character Zai at the end

Country	Form	Actual Shape
Jordan	ZiE2	
Morocco	ZiE3	
Oman	ZiE1	
Tunisia	ZiE1	

E. Character Za (Za) ظ

In its most common form, the shape of the character Za has two components, with the lower portion forming a complete circle, and the upper portion consisting of a straight vertical line. Within the context of this study, only the lower portion of this character has been considered, with the criteria

associated with this character being based on whether it is written as a full circle or triangle, which would either be cut at the end or terminated as a whole loop.

Initially, analysis of the handwriting samples identified six different forms of this character when written as unconnected and at the end, and seven different forms, at the start and in the middle as shown in Table 4.22.

Table 4.22: Character forms of character Za in different positions

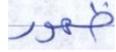
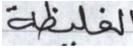
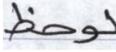
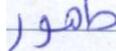
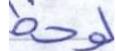
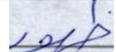
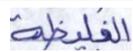
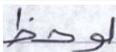
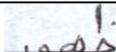
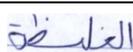
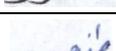
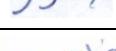
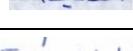
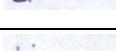
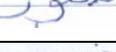
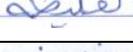
Form No.	Shape of the character forms in different positions				Description
	Unconnected (ZaU)	Start (ZaS)	Middle (ZaM)	End (ZaE)	
1					Circle with cutting
2					Circle without cutting
3					Triangle with cutting
4					Triangle without cutting
5					Za with additional stroke
6					Za written in one stroke
7	X			x	Za without vertical line

Figure 4.17 shows the association of this character when written as unconnected and shows that this character can be used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 1 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 2 was predominant).

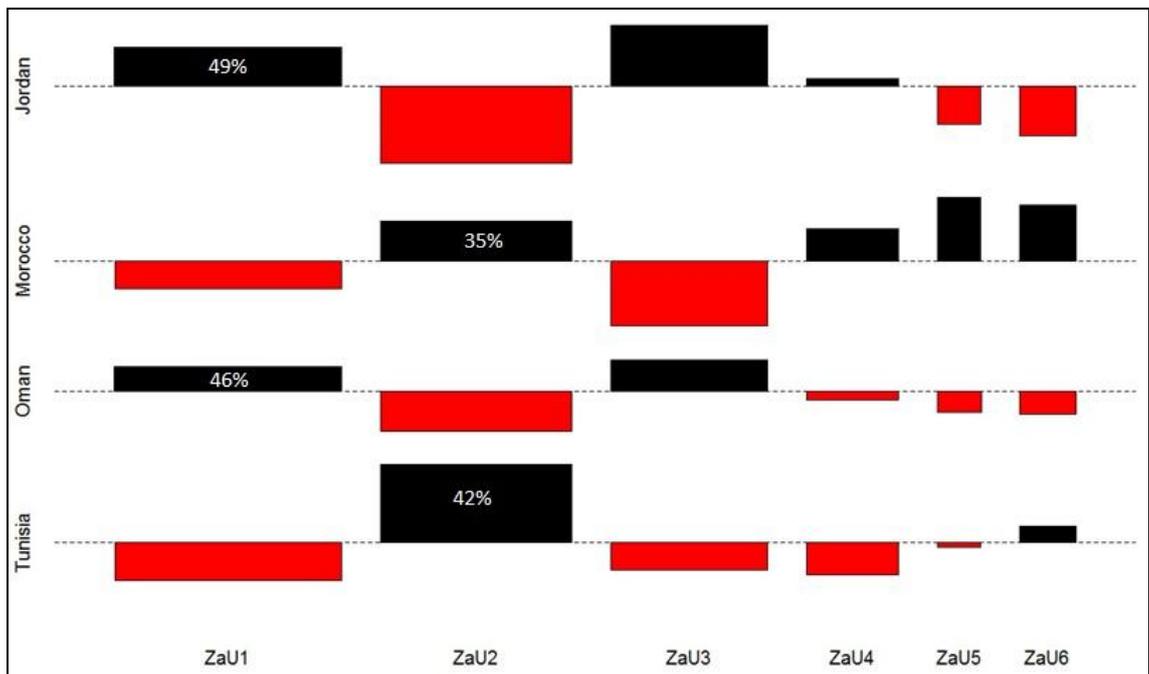


Figure 4.17: An association plot of the character Za unconnected.

Table 4.23 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.23: Actual letter shapes of the character Za unconnected

Country	Form	Actual Shape
Jordan	ZaU1	
Morocco	ZaU2	
Oman	ZaU1	
Tunisia	ZaU2	

Next when written at the start, the Figure 4.18 shows the association of this character when written at the start and that this character can be used to indicate that a writer was from Jordan (where form 1 was predominant), from Morocco (where form 5 was predominant), from Oman (where form 3 was predominant) or from Tunisia (where form 2 was predominant).

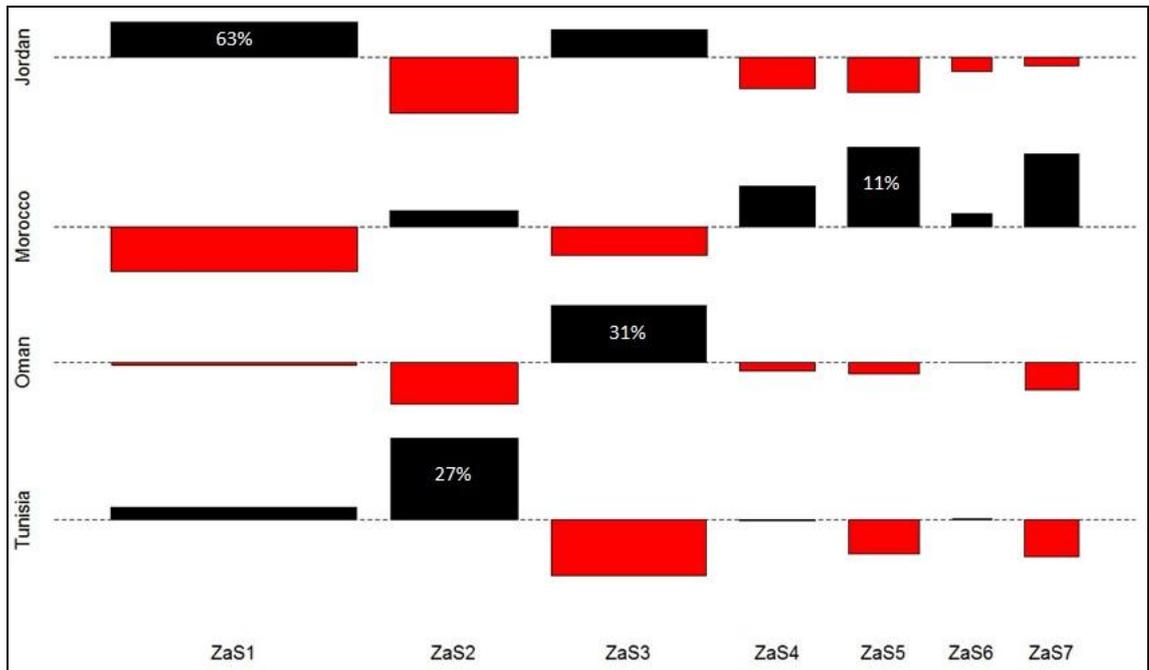


Figure 4.18: An association plot of the character Za at the start

Table 4.24 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.24: Actual letter shapes of the character Za at the start

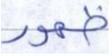
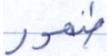
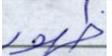
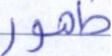
Country	Form	Actual Shape
Jordan	ZaS1	
Morocco	ZaS5	
Oman	ZaS3	
Tunisia	ZaS2	

Figure 4.19 shows the association of this character when written in the middle and that this character can be used to indicate that a writer was from Jordan (where form 1 was predominant, from the Western Region (i.e. Morocco or Tunisia where form 2 was predominant) or from Oman (where form 3 was predominant).

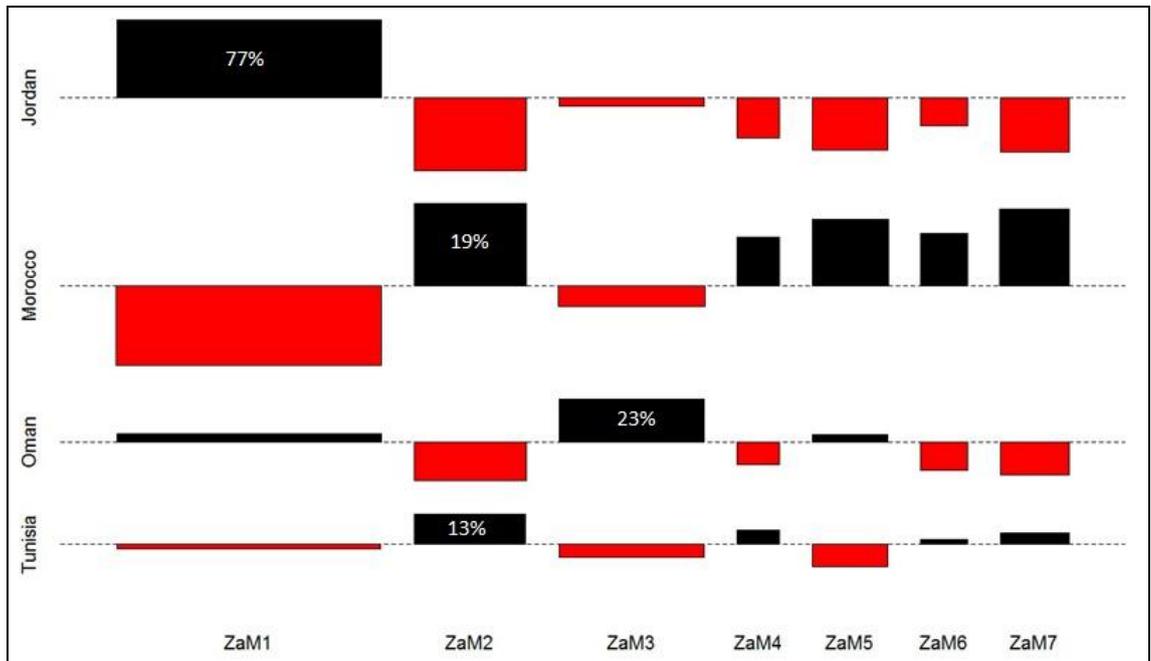


Figure 4.19: An association plot of the character Za in the middle

Table 4.25 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.25: Actual letter shapes of the character Za in the middle

Country	Form	Actual Shape
Jordan	ZaM1	
Morocco	ZaM2	
Oman	ZaM3	
Tunisia	ZaM2	

Figure 4.20 shows the association of this character when written at the end and that this character can be used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 1 was predominant), from Morocco (where form 6 was predominant) or from Tunisia (where form 2 was predominant).

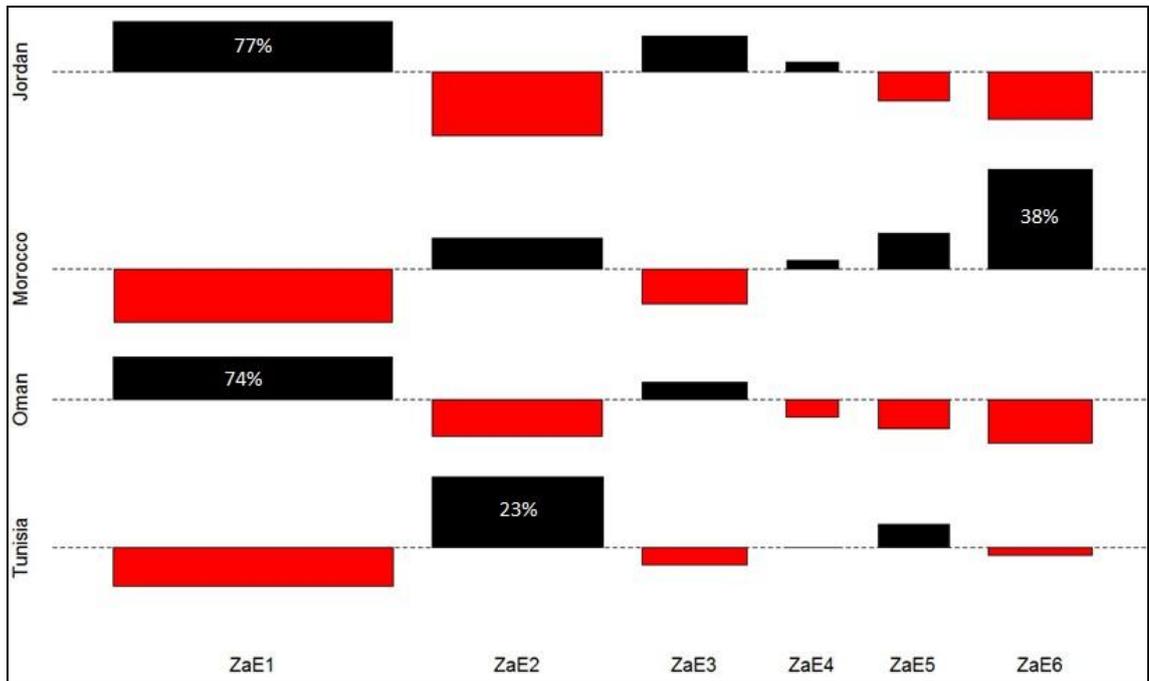
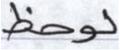
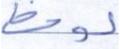
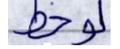
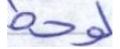


Figure 4.20: An association plot of the character Za at the end

Table 4.26 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.26: Actual letter shapes of the character Za at the end

Country	Form	Actual Shape
Jordan	ZaE1	
Morocco	ZaE6	
Oman	ZaE1	
Tunisia	ZaE2	

F. Character Ghayn (G) غ

The character Ghayn generally has two sections, an upper section, written above the line, and a lower section, written below the line when written as an unconnected character and at the end of a word. When written at the start or in the middle of a word, the lower section is not written.

For the purpose of this study, when this character is written as unconnected, both sections were considered, with the criteria associated with this character being based on whether the upper part was written as either a curve or straight line and the lower part as either an open or closed curve.

Initially, analysis of the handwriting samples identified four different forms as shown in Table 4.27.

Table 4.27: Character forms of character Ghayn unconnected

Form	Shape	Description
GU1		Curve - Opened curve
GU2		Curve - Closed curve
GU3		Line - Opened curve
GU4		Line - Closed curve

Figure 4.21 shows the association of this character when written as unconnected and shows that this character when written in this position can be used to indicate that a writer was from Jordan (where form 2 was predominant) or from Morocco, Oman or Tunisia (where form 1 was predominant).

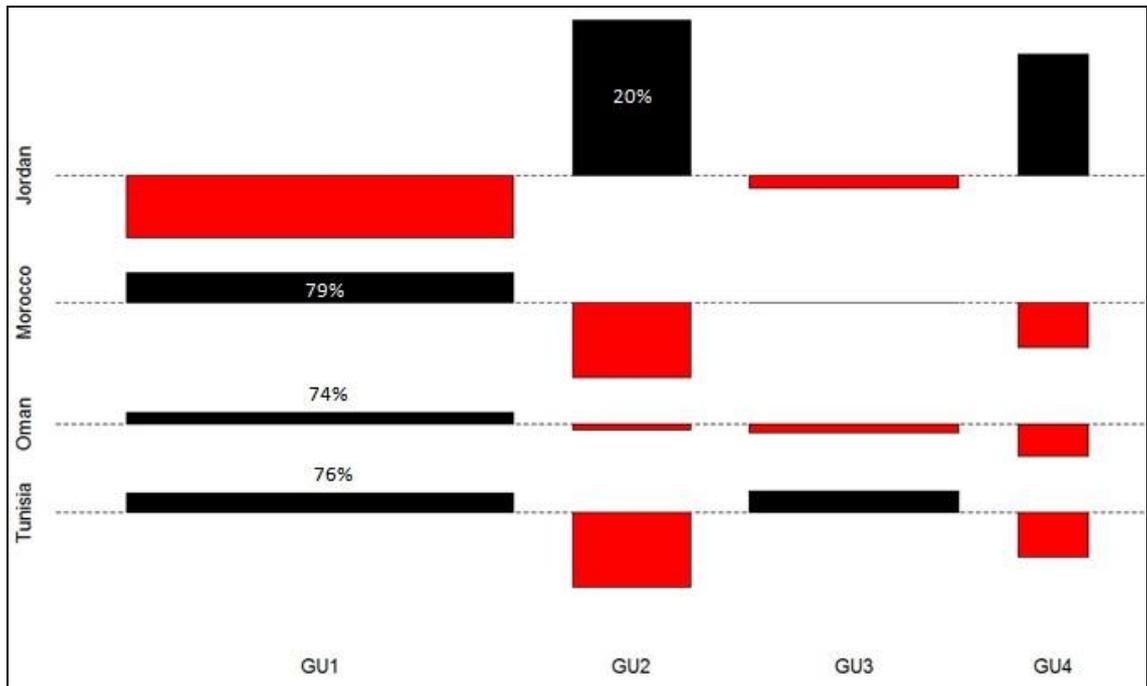


Figure 4.21: An association plot of the character Ghayn as unconnected

Table 4.28 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.28: Actual letter shapes of character Ghayn unconnected

Country	Form	Actual Shape
Jordan	GU2	
Morocco	GU1	
Oman	GU1	
Tunisia	GU1	

Next, when written at the start, only the upper part was considered, with the criteria associated with this character being based on whether the upper part was written as either a curve or straight line with or without a small line pointing downwards. Initially, analysis of the handwriting samples identified four different forms as shown in Table 4.29.

Table 4.29: Character forms of character Ghayn at the start

Form	Shape	Description
GS1		Curve with a small line pointing downwards at the start of the character
GS2		Curve without Line pointing downwards
GS3		Line with a small line pointing downwards at the start of the character
GS4		Line without line pointing downwards

Figure 4.22 shows the association of this character when written at the start and shows that this character when written in this position can be used to indicate that a writer was from Jordan (where form 4 was predominant), from the Western Region (i.e. Morocco or Tunisia where form 1 was predominant) or from Oman (where form 2 was predominant).

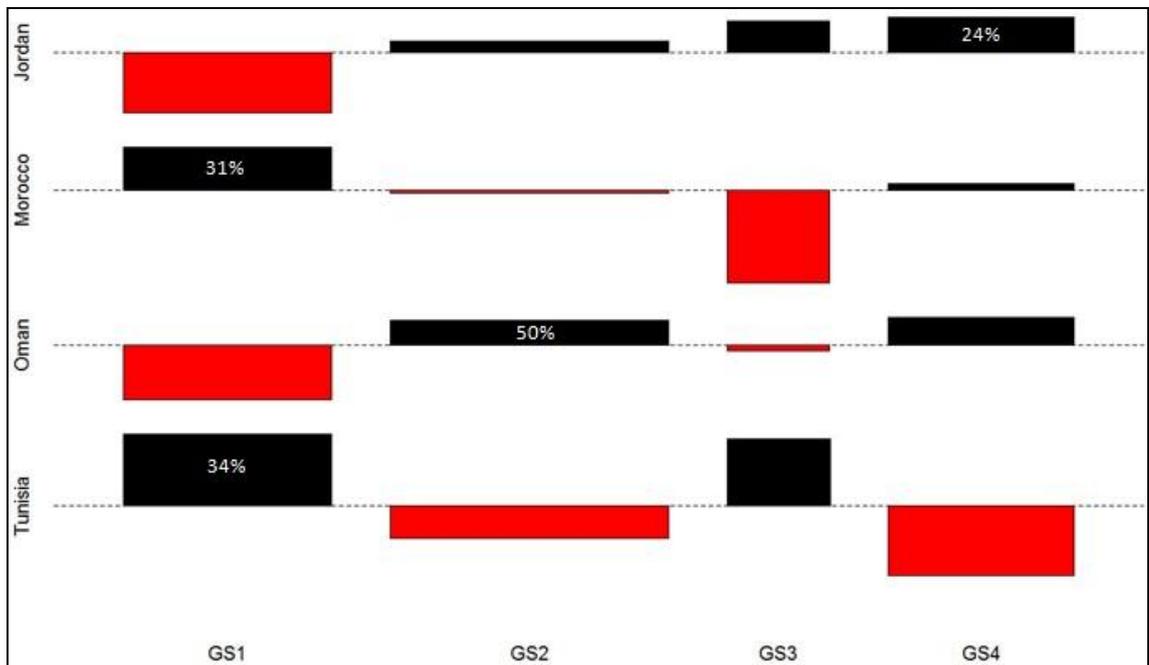


Figure 4.22: An association plot of the character Ghayn at the start

Table 4.30 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.30: Actual letter shapes of character Ghayn at the start

Country	Form	Actual Shape
Jordan	GS4	
Morocco	GS1	
Oman	GS2	
Tunisia	GS1	

Next, when character Ghayn is written in the middle and at the end, only the upper part was considered, with the criteria associated with this character being based on whether the upper part was written as closed or open and whether it is round, sharp or a line. Initially, analysis of the handwriting samples identified six different forms in each of both positions as shown in Table 4.31.

Table 4.31: Character forms of character Ghayn in the middle and at the end

Form No.	Shape		Description
	Middle (GM)	End (GE)	
1			Round
2			Sharp - Sharp
3			Sharp - Round
4			Round - Sharp
5			Open
6			Line

Figure 4.23 shows the association of this character when written in the middle and shows that this character when written in this position can be used to indicate that a writer was either from Eastern Region (i.e. Jordan or Oman where form 1 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 2 was predominant).

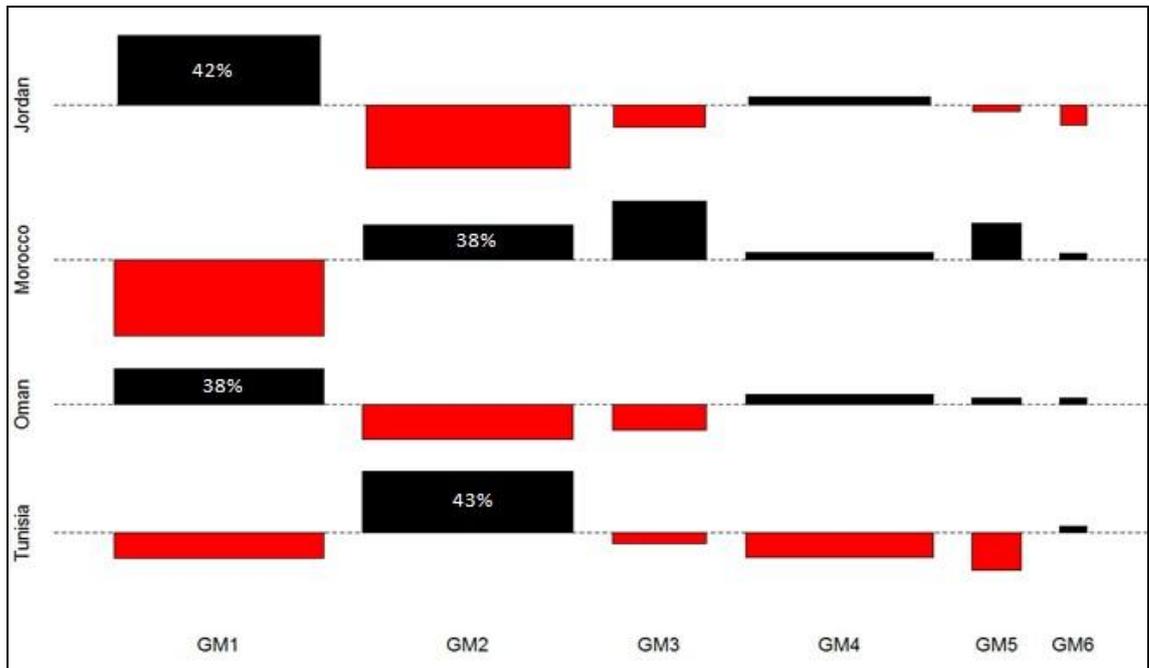


Figure 4.23: An association plot of the character Ghayn in the middle

Table 4.32 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.32: Actual letter shapes of the character Ghayn in the middle

Country	Form	Actual Shape
Jordan	GM1	الفناء
Morocco	GM2	الغذاء
Oman	GM1	الفناء
Tunisia	GM2	الغذاء

Figure 4.24 shows the association of this character when written at the end and that this character when written in this position can be used to indicate that a writer was either from Eastern Region (i.e. Jordan or Oman where form 1 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 2 was predominant).

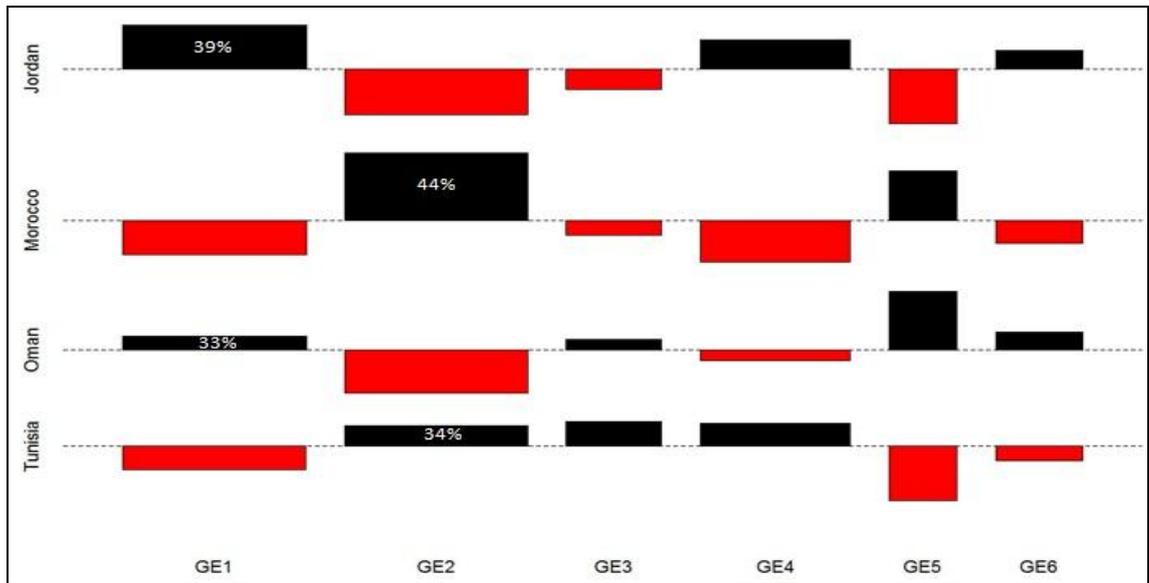


Figure 4.24: An association plot of the character Ghayn at the end

Table 4.33 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.33: Actual letter shapes of the character Ghayn at the end

Country	Form	Actual Shape
Jordan	GE1	
Morocco	GE2	
Oman	GE1	
Tunisia	GE2	

G. Character Kaf (ك)

The character Kaf takes on a characteristic form and different shapes when written as an unconnected character compared to when this character is part of a word. For the purposes of this study, when this character was written as unconnected, it was split into two components, an upper and a lower component and whether the character was written in a single or double stroke, curve or straight line with or without glottal stop (GS), an integral part of the character.

Initially, analysis of the handwriting samples identified six different forms of this character when written unconnected as shown in Table 4.34.

Table 4.34: Character forms of character Kaf unconnected

Form	Shape	Description
KU1		Single stroke - curve with glottal stop
KU2		Single stroke – Line with glottal stop
KU3		Single stroke - circle without glottal stop
KU4		Double strokes - line curve with glottal stop
KU5		Double strokes -line circle without glottal stop
KU6		Double strokes - line line without glottal stop

Figure 4.25 shows the association of this character when written as unconnected and that this character can be used to indicate that a writer was from the Eastern Region (i.e. Jordan or Oman where form 1 was predominant), from Morocco (where form 2 was predominant) or from Tunisia (where form 6 was predominant).

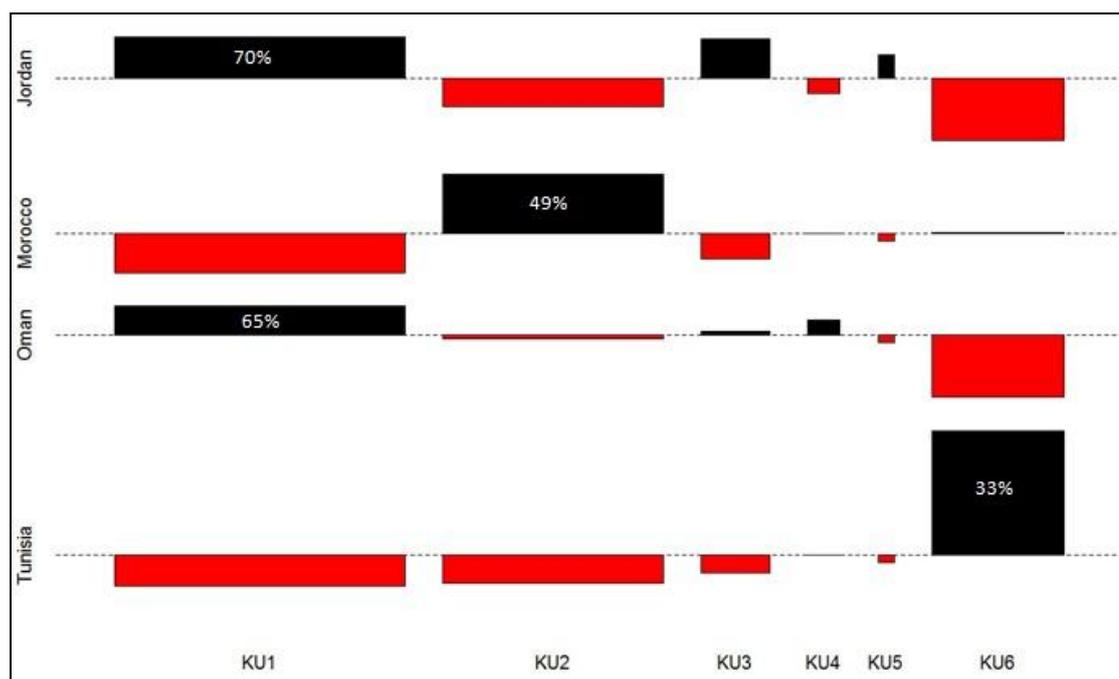


Figure 4.25: An association plot of the character Kaf unconnected

Table 4.35 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.35: Actual letter shapes of the character Kaf unconnected

Country	Form	Actual Shape
Jordan	KU1	
Morocco	KU2	
Oman	KU1	
Tunisia	KU6	

Next, when Kaf was written at the start it was also split into two portions, an upper and lower portion. These are classified as combinations of curves and/or lines to determine whether the two components were connected or unconnected which signifies whether the character was written in a single stroke or in two separate strokes.

Initially, analysis of the handwriting samples identified ten different forms of this character when written at the start as shown Table 4.36.

Table 4.36: Character forms of character Kaf at the start

Form No.	Form	Description
KS1		Two Curves Connected
KS2		Two Curves Unconnected
KS3		Line Curve Connected
KS4		Line Curve Unconnected
KS5		Two Lines Connected
KS6		Two Lines Unconnected
KS7		Curve Line Connected
KS8		Curve Line Unconnected
KS9		Line Closed curve Connected
KS10		Line Closed curve Unconnected

Figure 4.26 shows the association of this character when written at the start and that this character can be used to indicate that a writer was from Jordan (where form 1 was predominant), from Morocco (where form 3 was predominant), from Oman (where form 4 was predominant) or from Tunisia (where form 5 was predominant).

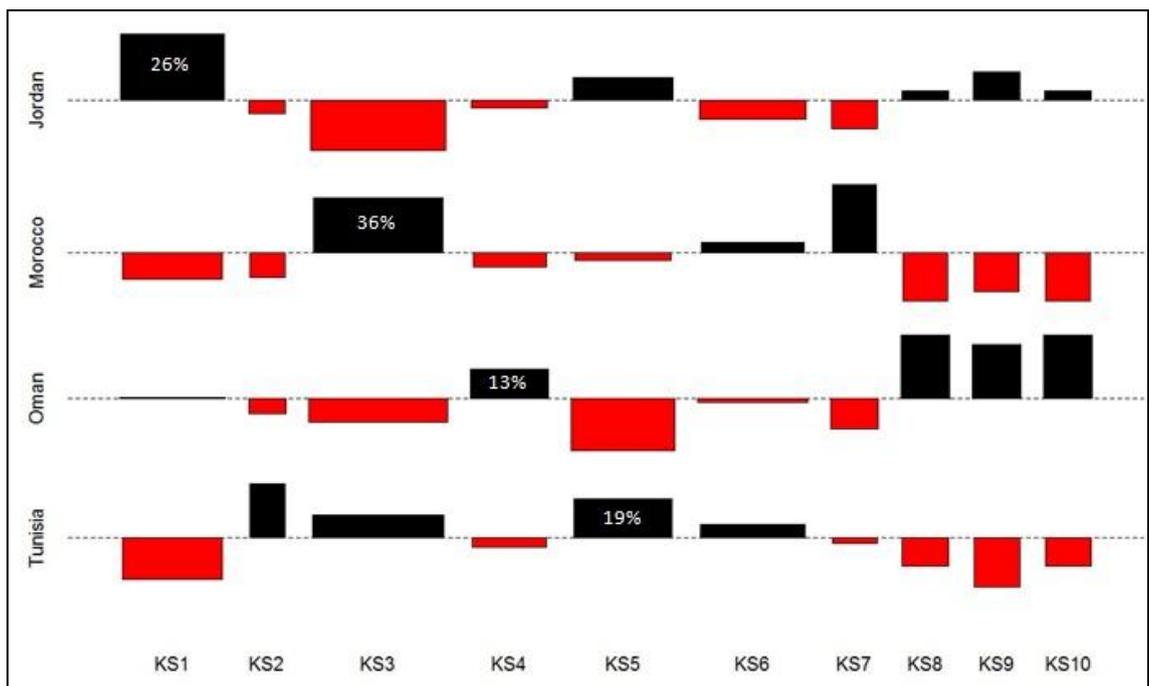


Figure 4.26: An association plot of the character Kaf at the start

Table 4.37 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.37: Actual letter shapes of the character Kaf at the start

Country	Form	Actual Shape
Jordan	KS1	
Morocco	KS3	
Oman	KS4	
Tunisia	KS5	

The criteria used for situations in which the character Kaf was placed in the middle of a word were the same as when written at the beginning of a word. However, initially analysis of the handwriting samples identified eight different forms as shown in Table 4.38 below.

Table 4.38: Character forms of character Kaf in the middle

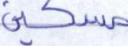
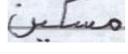
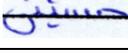
Form No.	Form	Description
KM1		Two Curves Connected
KM2		Two Curves Unconnected
KM3		Line Curve Connected
KM4		Line Curve Unconnected
KM5		Two Lines Connected
KM6		Two Lines Unconnected
KM7		Curve Line Connected
KM8		Curve Line Unconnected

Figure 4.27 shows the association of this character when written in the middle and that this character can be used to indicate that a writer was from Jordan (where form 7 was predominant), from Morocco or Tunisia (where form 5 was predominant) or from Oman (where form 1 was predominant).

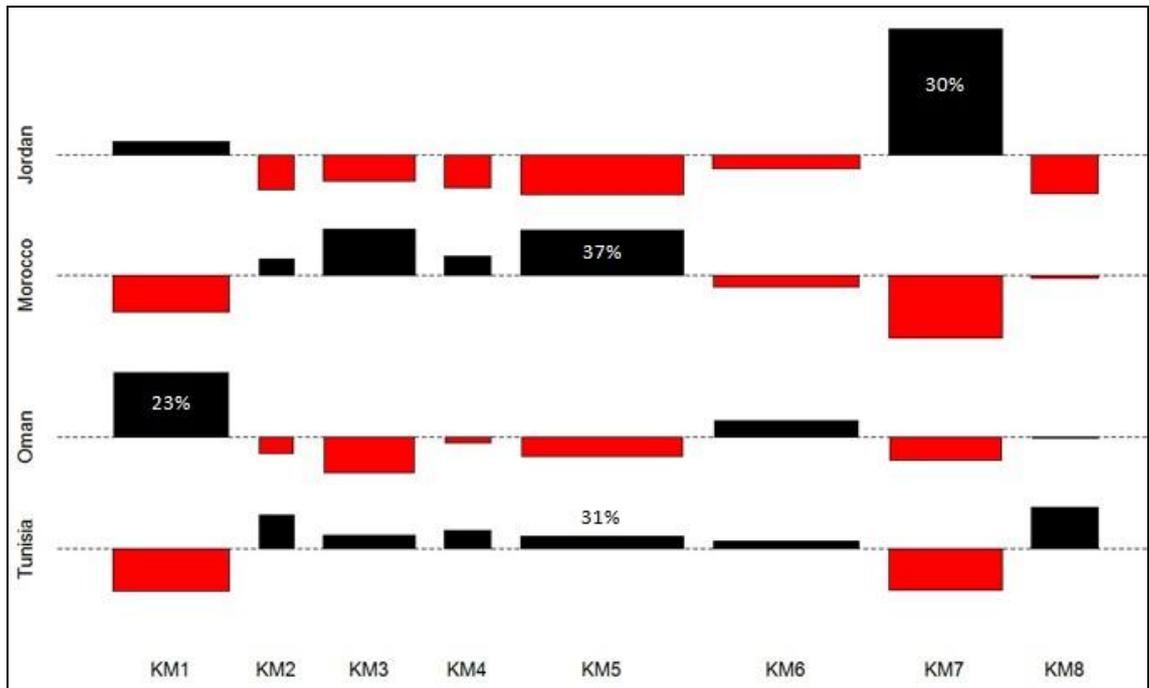


Figure 4.27: An association plot of the character Kaf in the middle

Table 4.39 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.39: Actual letter shapes of the character Kaf in the middle

Country	Form	Actual Shape
Jordan	KM7	
Morocco	KM5	
Oman	KM1	
Tunisia	KM8	

When placed at the end of a word, the character Kaf takes on a different shape as compared with when it is written in the middle or at the start of a word. However, when written at the end of a word, this character takes on the same shape as when it is written as an unconnected character. Therefore, the criteria used in order to analyse these data were the same as when the character Kaf is written as an unconnected character as shown in Table 4.40.

Table 4.40: Character forms of character Kaf at the end

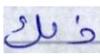
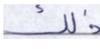
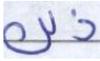
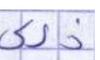
Form	Shape	Description
KE1		Single stroke - curve with glottal stop (GS)
KE2		Single stroke – Line with (GS).
KE3		Single stroke - circle without (GS)
KE4		Double strokes –two curves connected without (GS)
KE5		Double strokes - Line Curve connected without GS
KE6		Double strokes- two Lines unconnected without (GS)

Figure 4.28 shows the association of this character when written at the end and shows that this character when written at this position can be used to indicate that a writer was either from the Eastern Region (i.e. Jordan or Oman where form 1 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 6 was predominant).

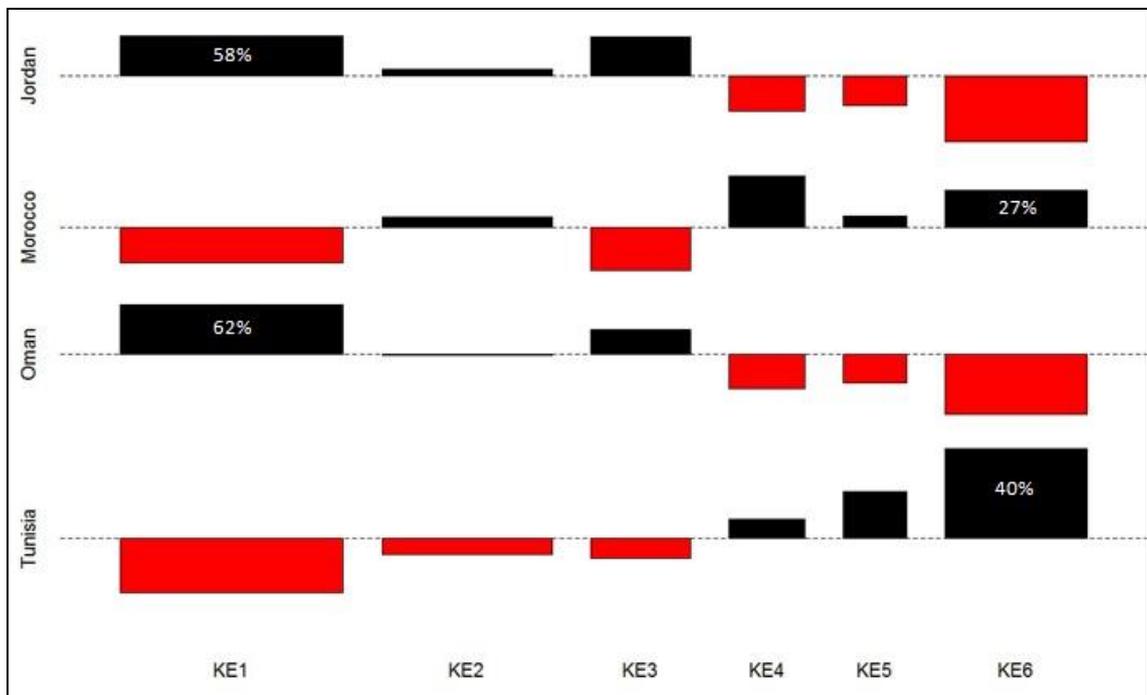


Figure 4.28: An association plot of the character Kaf at the end

Table 4.41 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.41: Actual letter shapes of the character Kaf at the end

Country	Form	Actual Shape
Jordan	KE1	
Morocco	KE6	
Oman	KE1	
Tunisia	KE6	

H. Character Meem (M) م

The character Meem generally has two sections, an upper section, written above the line, and a lower section as a vertical line written below the writing line. When written at the beginning of a word, it is common for only the upper section to be shown. This is also commonly the case when written in the middle of a word, connecting the preceding and following characters. However, when this character is written at the end of a word, it is written in its full form. With regard to this study, the focus was the starting point of the upper section of the character in regard to how it is written. Regardless of the position of this character, the criteria used for data analysis consisted of whether the character starts from the left, right, up, or down and whether it is written in a counterclockwise direction.

Initially, analysis of the handwriting samples identified five different forms when this character was written as unconnected as shown in Table 4.42.

Table 4.42: Character forms of character Meem unconnected

Form	Shape	Description
MU1		Start from down
MU2		Start from up
MU3		Start from left
MU4		Start from right
MU5		Anticlockwise

Figure 4.29 shows the association of this character when written unconnected and shows that can be used to indicate that a writer was from Jordan, Morocco or Oman (where form 1 was predominant) or from Tunisia (where form 5 was predominant).

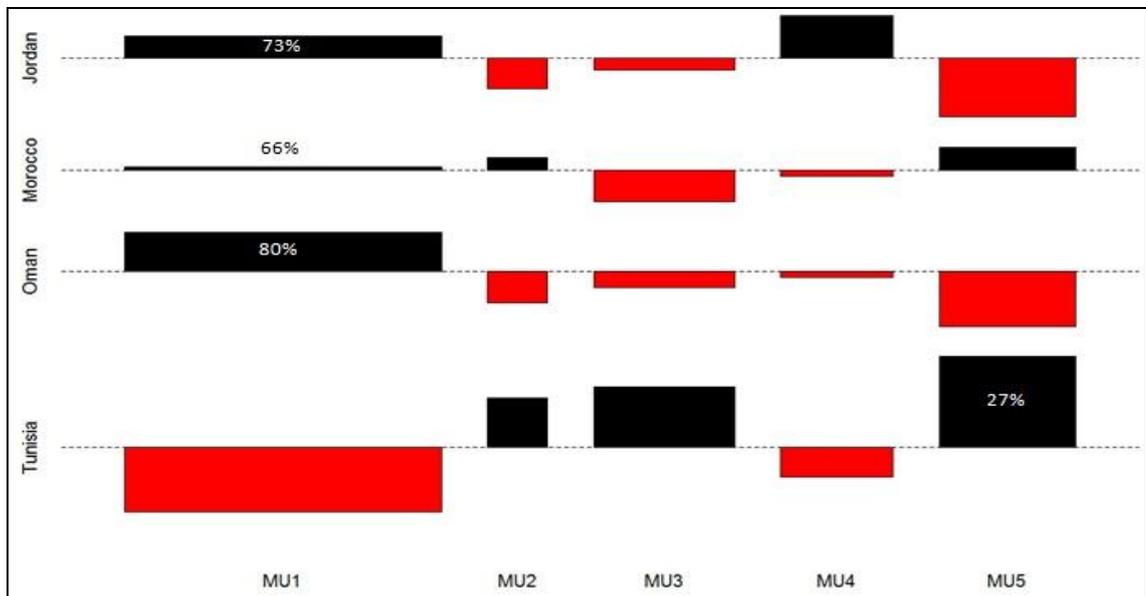


Figure 4.29: An association plot of the character Meem as unconnected

Table 4.43 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.43: Actual letter shapes of the character Meem as unconnected

Country	Form	Actual Shape
Jordan	MU1	
Morocco	MU1	
Oman	MU1	
Tunisia	MU5	

When character Meem written at the start of the word, five different forms were identified as shown in Table 4.44.

Table 4.44: Character forms of character Meem at the start

Form	Shape	Description
MS1		Start from down moving upwards
MS2		Start from up to downwards
MS3		Start from left
MS4		Start from right
MS5		Anti clockwise

Figure 4.30 shows the association of this character when written at the start and shows that it can be used to indicate that a writer was from Jordan (where form 4 was predominant), from Morocco (where form 2 was predominant), from Oman (where form 5 was predominant) or from Tunisia (where form 3 was predominant).

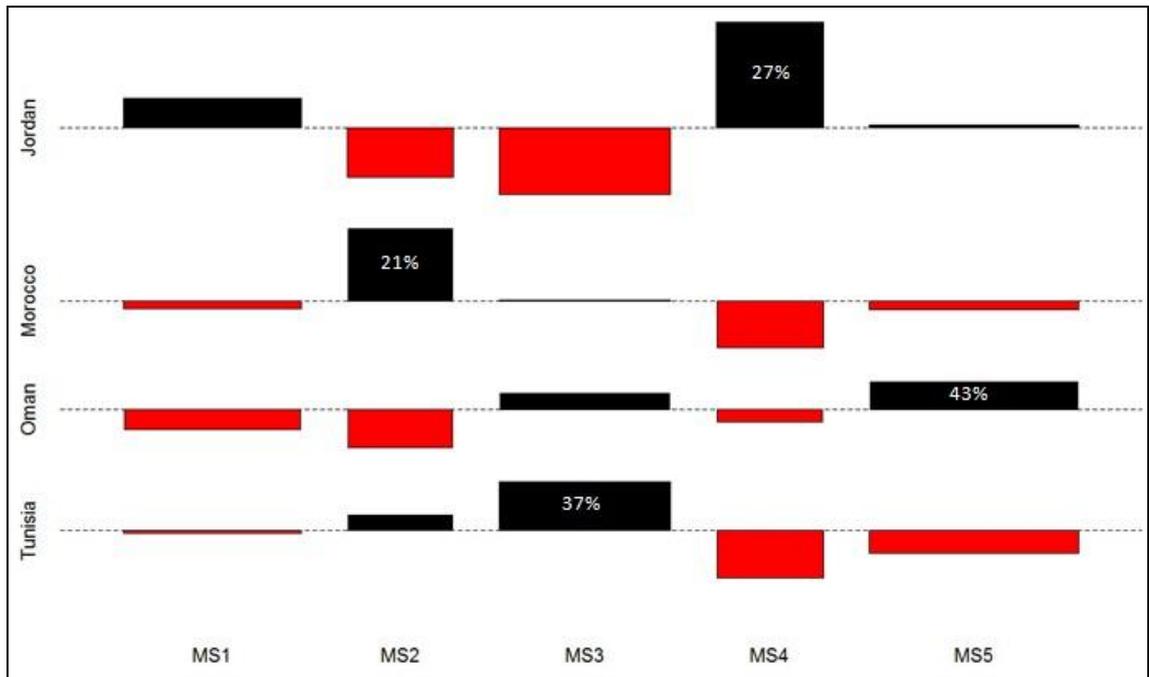


Figure 4.30: An association plot of the character Meem at the start

Table 4.45 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.45: Actual letter shapes of the character Meem at the start

Country	Form	Actual Shape
Jordan	MS4	
Morocco	MS2	
Oman	MS5	
Tunisia	MS3	

When this character written in the middle, six different forms was identified as shown in Table 4.46.

Table 4.46: Character forms of character Meem in the middle

Form	Shape	Description
MM1		Start from down
MM2		Start from Up
MM3		Start from right
MM4		Start from left
MM5		Anticlockwise (up)
MM6		Anticlockwise (down)

Figure 4.31 shows the association of this character when written in the middle and shows that it can be used to indicate that a writer was from Jordan (where form 3 was predominant), either from the Western Region (i.e. Morocco or Tunisia where form 4 was predominant) or from Oman (where form 5 was predominant).

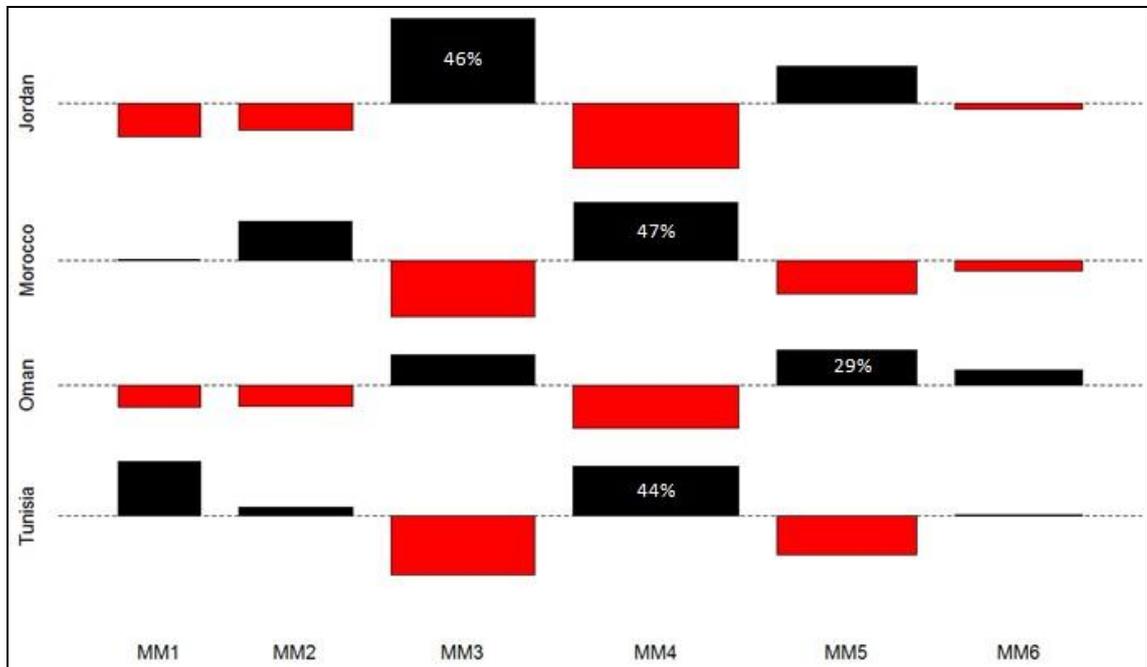


Figure 4.31: An association plot of the character Meem in the middle

Table 4.47 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.47: Actual letter shapes of the character Meem in the middle

Country	Form	Actual Shape
Jordan	MM3	
Morocco	MM4	
Oman	MM5	
Tunisia	MM4	

Finally, when the character Meem was written at the end of the word, six different forms were identified as shown in Table 4.48.

Table 4.48: Character forms of character Meem at the end

Form	Shape	Description
ME1		Start from down
ME2		Start from up
ME3		Start from right
ME4		start from left
ME5		Anticlockwise - down
ME6		Anticlockwise -up

Figure 4.32 shows the association of this character when written at the end and shows that this character when written in this position can be used to indicate that a writer was either from Eastern Region (i.e. Jordan or Oman where form 3 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 1 was predominant).

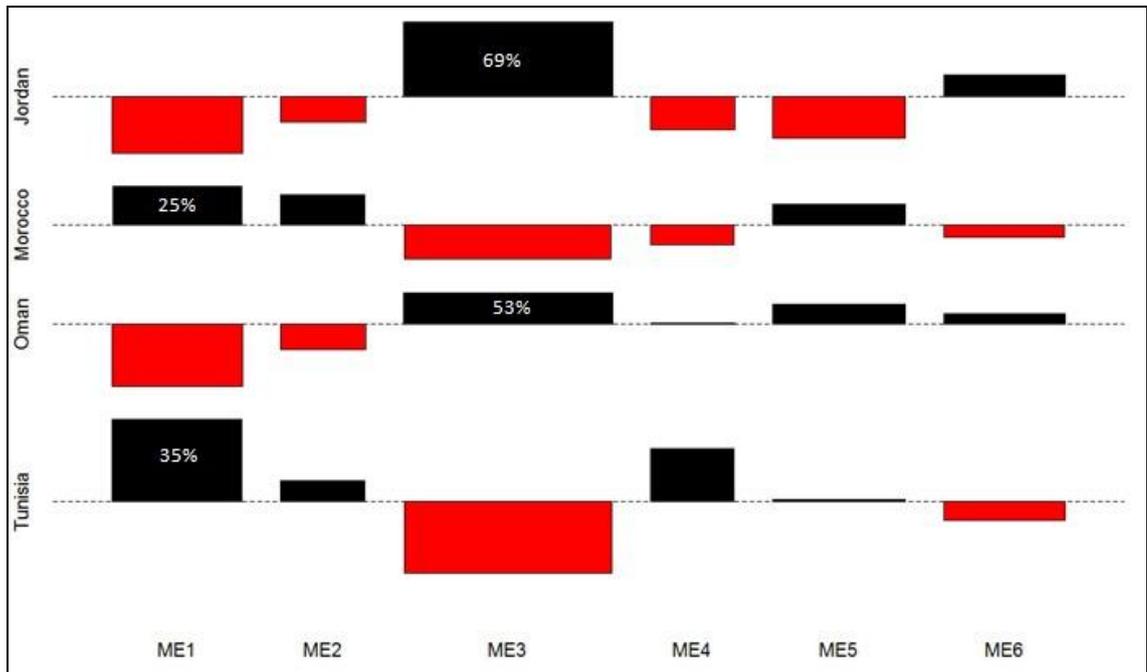


Figure 4.32: An association plot of the character Meem at the end

Table 4.49 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.49: Actual letter shapes of the character Meem at the end

Country	Form	Actual Shape
Jordan	ME3	
Morocco	ME1	
Oman	ME3	
Tunisia	ME1	

I. Character Haa (H) هـ

The Arabic character Haa is unique, as no other character takes the same shape. In addition, this character is very distinct in that when written unconnected and at the start of a word, it takes a similar shape. This character takes on different shapes when written in either the middle or at the end of a word. Compared to the other characters focused in this study, data collection for the character Haa was conducted differently. Specifically, the focus of the criteria associated with this character, four different positions were based on

how the writer begins to write this character, as opposed to dividing this character into multiple parts. This is one of the more unusual characters in the Arabic alphabet as there is little resemblance between its multiple forms.

Initially, analysis of the handwriting samples identified five different forms when this character written as unconnected, as shown in Tables 4.50.

Table 4.50: Character forms of character Haa unconnected

Form	Shape	Description
HU1		Start from down moving upwards
HU2		Start from Left
HU3		Start from right
HU4		Start from up
HU5		Anticlockwise

The Figure 4.33 shows the association of this character when written as unconnected and shows that this character when written in this position can be used to indicate that a writer was either from Eastern Region (i.e. Jordan or Oman where form 1 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 2 was predominant).

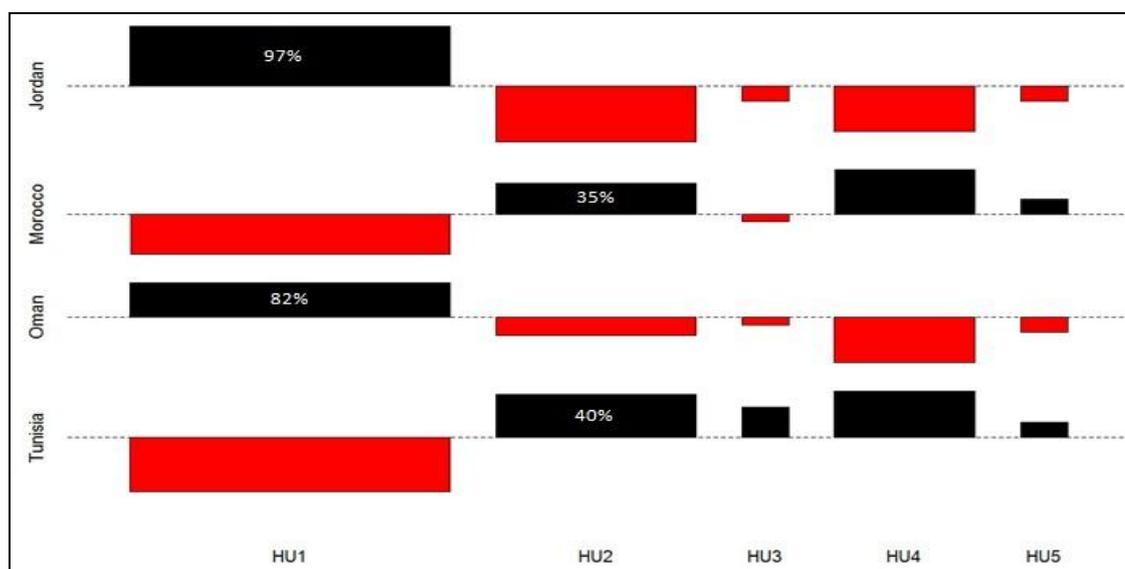


Figure 4.33: An association plot of the character Haa as unconnected

Table 4.51 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.51: Actual letter shapes the character Haa as unconnected

Country	Form	Actual Shape
Jordan	HU1	
Morocco	HU2	
Oman	HU1	
Tunisia	HU2	

Next, when character Haa written at the start of a word, four different forms were identified as shown in Table 4.52.

Table 4.52: Character forms of character Haa at start

Form	Shape	Description
HS1		Start from down moving upwards
HS2		Start from left to right
HS3		Start from up to downwards
HS4		Anticlockwise

Figure 4.34 shows the association of this character when written at the start and shows that can be used to indicate that a writer was either from Eastern Region (i.e. Jordan or Oman where form 1 was predominant), from Morocco (where form 3 was predominant) or from Tunisia (where form 2 was predominant).

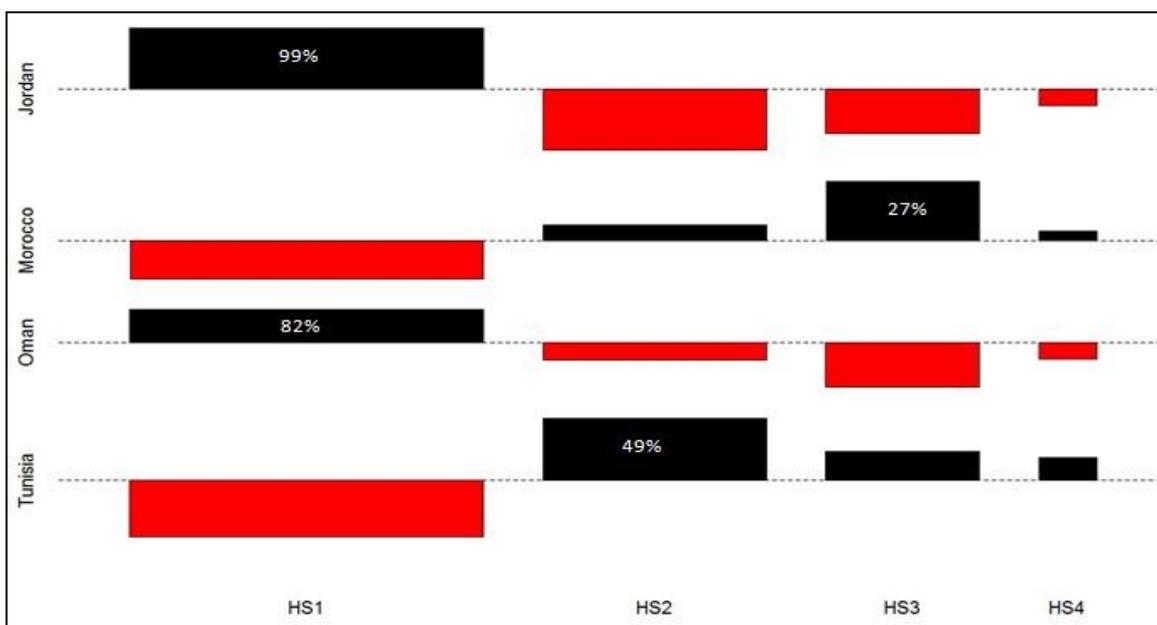


Figure 4.34: An association plot of the character Haa at the start

Table 4.53 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.53: Actual letter shapes of the character Haa at the start

Country	Form	Actual Shape
Jordan	HS1	
Morocco	HS3	
Oman	HS1	
Tunisia	HS2	

Next, when character Haa written in the middle of a word, eleven different forms were identified as shown in Table 4.54.

Table 4.54: Character forms of character Haa in the middle

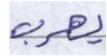
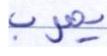
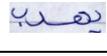
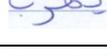
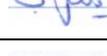
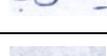
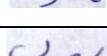
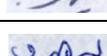
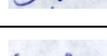
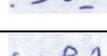
Form	Shape	Description
HM1		Start from down and 2 full circles, one inside the other
HM2		Start from down and 2 circles outside each other
HM3		Start from left and two circles one inside the other
HM4		Start from left and two circles outside each other
HM5		Start from Up and two circles outside each other
HM6		Start from down and two circles adjacent to each other
HM7		Start from right and two circles one over the other (Up)
HM8		Start from right and sharp line without a circle
HM9		Start from right and sharp line with 2 circles one inside the other
HM10		Start from right and 2 separated circles one above the other (Down)
HM11		Starting from right and sharp line with only one circle

Figure 4.35 shows the association of this character when written in the middle and shows that can be used to indicate that a writer was from Jordan (where form 8 was predominant), from the Western Region (i.e. Morocco or Tunisia where form 5 was predominant) or from Oman (where form 1 was predominant).

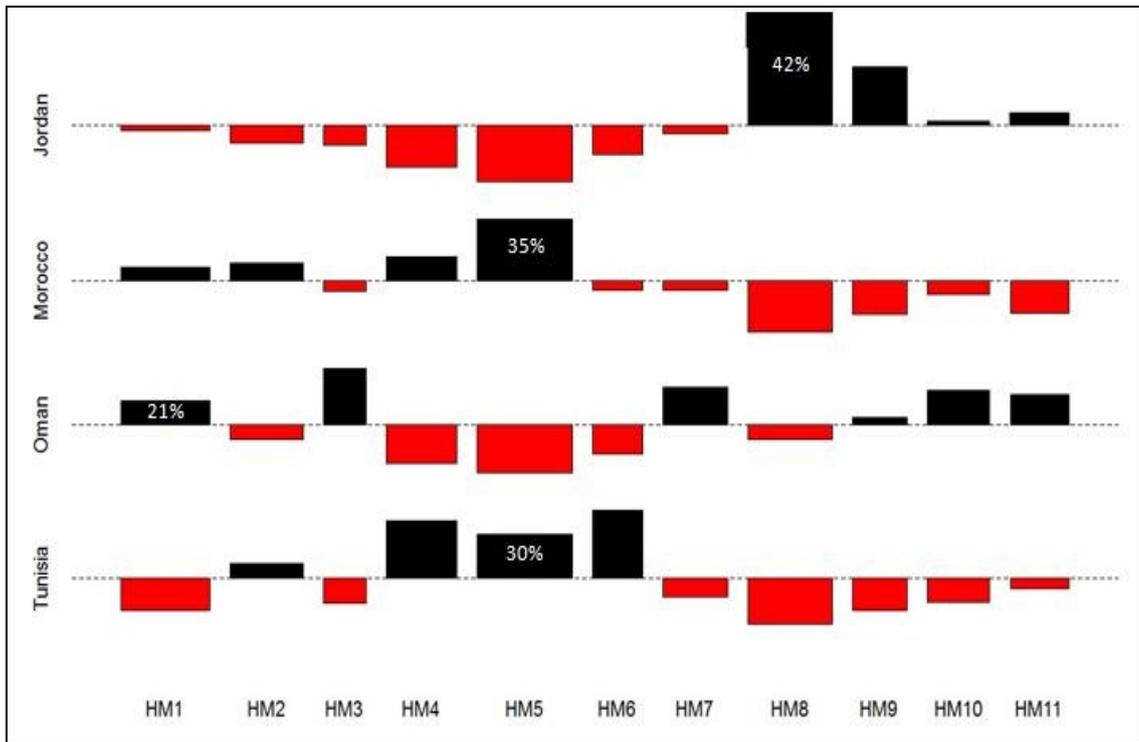


Figure 4.35: An association plot of the character Haa in the middle

Table 4.55 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.55: Actual letter shapes of the character Haa in the middle

Country	Form	Actual Shape
Jordan	HM8	
Morocco	HM5	
Oman	HM1	
Tunisia	HM5	

Finally, eight different forms were identified when this character is written at the end of a word, as shown in Table 4.56.

Table 4.56: Character forms of character Haa at the end

Form	Shape	Description
HE1		Anticlockwise with a circle without a line
HE2		Anticlockwise with a circle with a line
HE3		Anticlockwise with a triangle without a line
HE4		Anticlockwise with a triangle with a line
HE5		Clockwise with a circle without a line
HE6		Clockwise with a circle with a line
HE7		Clockwise with a triangle without a line
HE8		Clockwise with a triangle with a line

Figure 4.36 shows the association of this character when written at the end and shows that it can be used to indicate that a writer was either from Jordan or Tunisia (where form 1 was predominant), from Morocco (where form 5 was predominant) or Oman (where form 2 was predominant).

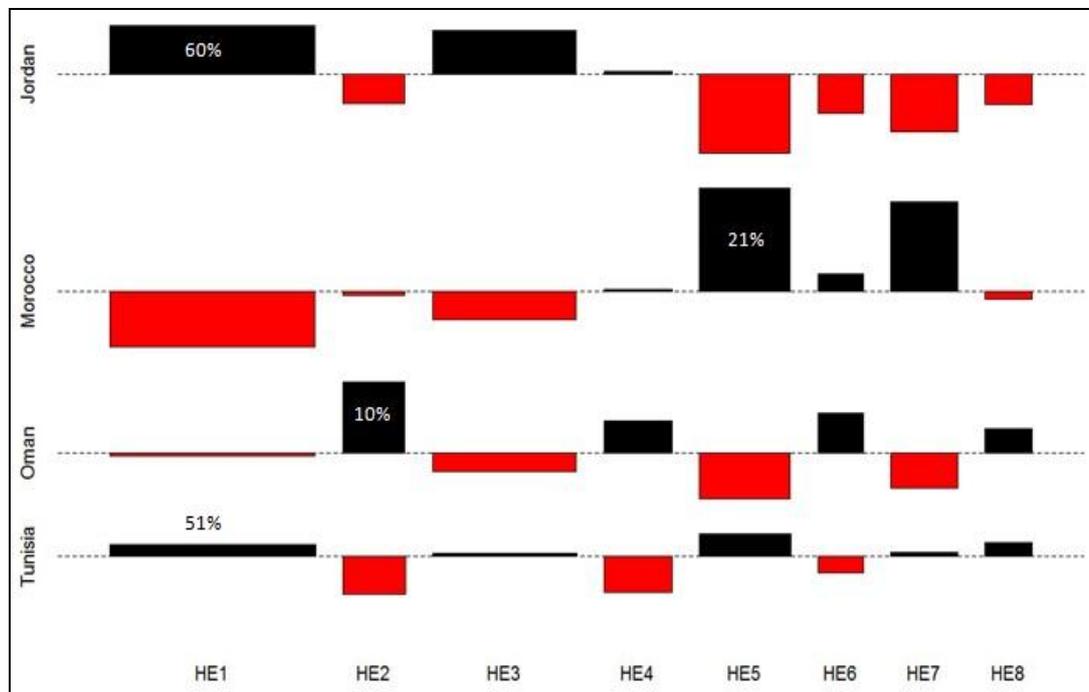


Figure 4.36: An association plot of the character Haa at the end

Table 4.57 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.57: Actual letter shapes of the character Haa at the end

Country	Form	Actual Shape
Jordan	HE1	
Morocco	HE5	
Oman	HE2	
Tunisia	HE1	

J. Character Yaa (Y) ي

The Arabic character Yaa has a unique form, with no other Arabic characters taking the same shape. This character is also distinct in that when written as an unconnected character and at the end of a word, it takes on a similar shape. It also takes on similar shapes when written at the start or in the middle of a word. The criteria used for the four positions identified are based on how the writer starts to write the character and the formation used at the start of the character.

First, when character Yaa was written as unconnected, initially analysis of the handwriting samples identified four different forms, as shown in Tables 4.58.

Table 4.58: Character forms of character Yaa unconnected

Form	Shape	Description
YU1		Start with a curve and long end
YU2		Start with a curve without long end
YU3		Start with a line and long end
YU4		Start with a line without long end

Figure 4.37 shows the association of this character when written as unconnected and shows that it can be used to indicate that a writer was from Jordan (where form 4 was predominant), from the Western Region (i.e.

Morocco or Tunisia where form 1 was predominant) or Oman (where form 2 was predominant).

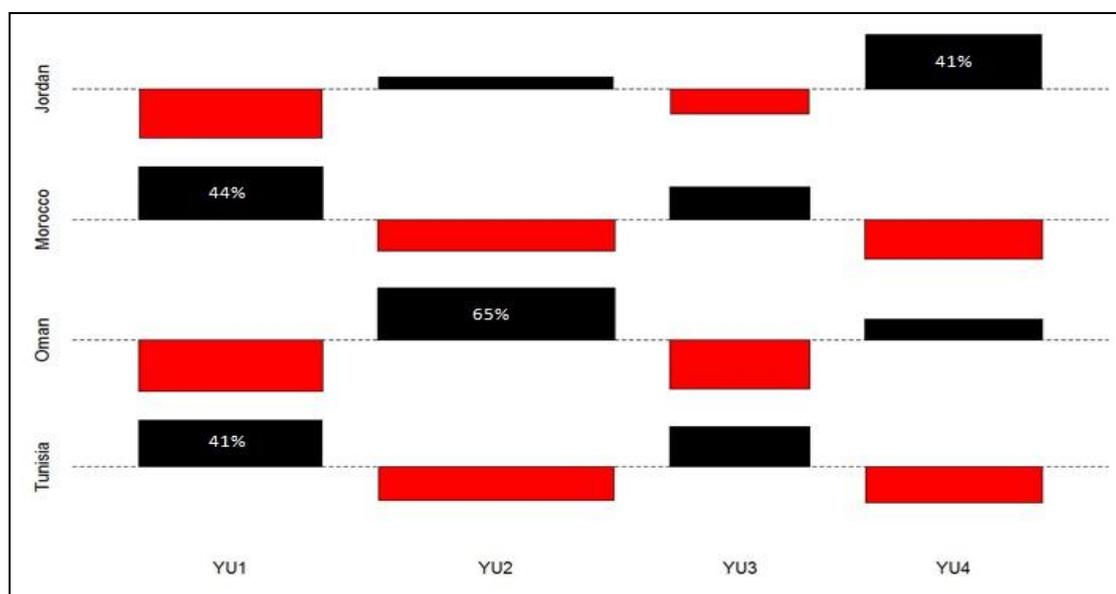


Figure 4.37: An association plot of the character Yaa as unconnected.

Table 4.59 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.59: Actual letter shapes of the character Yaa as unconnected

Country	Form	Actual Shape
Jordan	YU4	
Morocco	YU1	
Oman	YU2	
Tunisia	YU1	

Next, four different forms were identified when this character written at the start of a word, as shown in Table 4.60.

Table 4.60: Character forms of character Yaa at the start

Form	Shape	Description
YS1		Start with a curve
YS2		Start with a line to left
YS3		Start with a line to up
YS4		Start without edge

Figure 4.38 shows the association of this character when written at the start and shows that can be used to indicate that a writer was from Jordan (where form 3 was predominant), from the Western Region (i.e. Morocco or Tunisia where form 1 was predominant) or Oman (where form 2 was predominant).

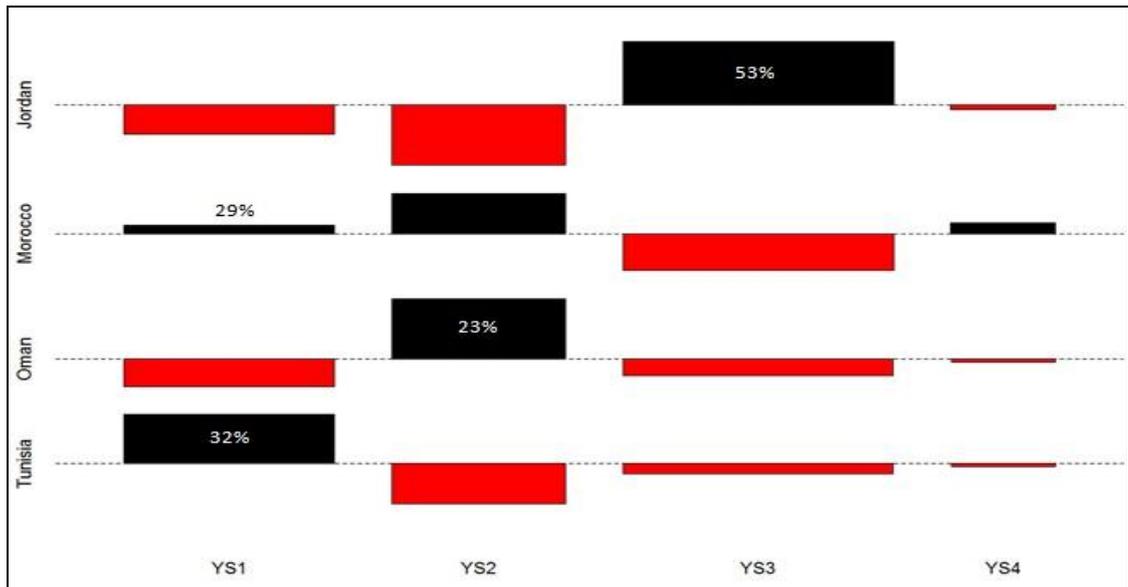


Figure 4.38: An association plot of the character Yaa at the start

Table 4.61 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.61: Actual letter shapes of the character Yaa at the start

Country	Form	Actual Shape
Jordan	YS3	
Morocco	YS1	
Oman	YS2	
Tunisia	YS1	

Next, four different forms were identified when this character was written in the middle, as shown in Table 4.62.

Table 4.62: Character forms of character Yaa in the middle

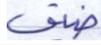
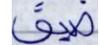
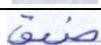
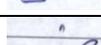
Form	Shape	Description
YM1		Start with a line to up
YM2		Start with a line to left
YM3		Start with a line to right
YM4		Start without edge

Figure 4.39 shows the association of this character when written in the middle and shows that can be used to indicate that a writer was from the Eastern Region (i.e. Jordan or Oman where form 4 was predominant) or from the Western Region (i.e. Morocco or Tunisia where form 1 was predominant).

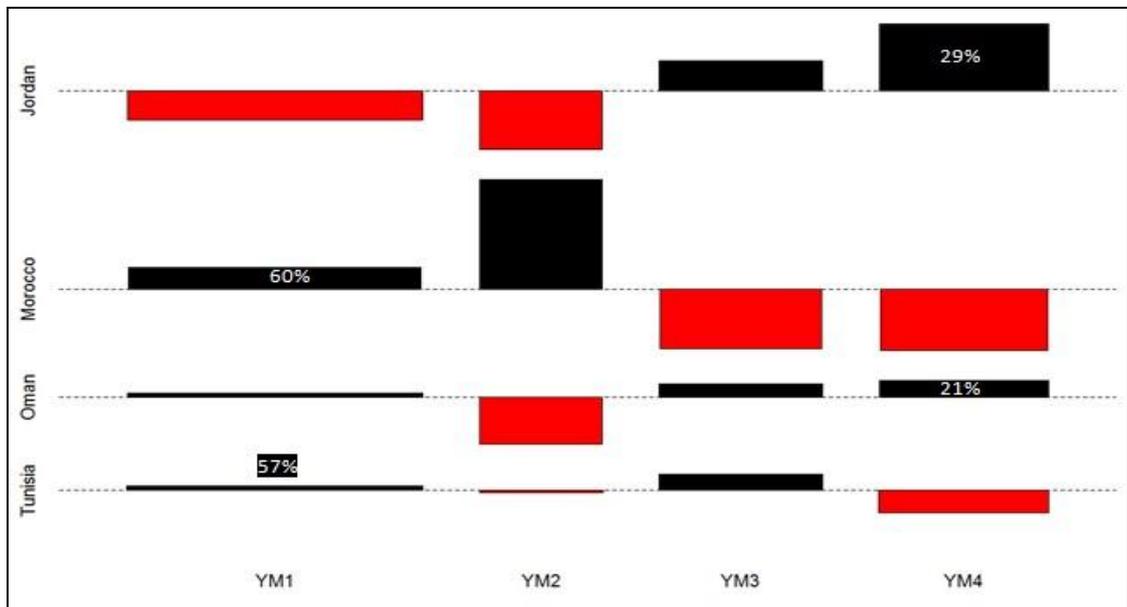


Figure 4.39: An association plot of the character Yaa in the middle

Table 4.63 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.63: Actual letter shapes of the character Yaa in the middle

Country	Form	Actual Shape
Jordan	YM4	
Morocco	YM1	
Oman	YM4	
Tunisia	YM1	

Finally, four different forms were identified when this character written at the end, as shown in Table 4.64.

Table 4.64: Character forms of character Yaa at the end

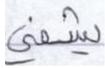
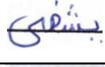
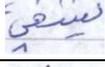
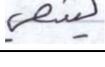
Form	Shape	Description
YE1		Start with a curve and curve joining edge
YE2		Start with a line and sharp joining edge
YE3		Start with a line and without joining edge
YE4		Start with a curve and without joining edge

Figure 4.40 shows the association of this character when written at the end and shows that can be used to indicate that a writer was from Jordan (where form 4 was predominant), from Morocco (where form 3 was predominant), from Oman (where form 1 was predominant) or form Tunisia (where form 2 was predominant).

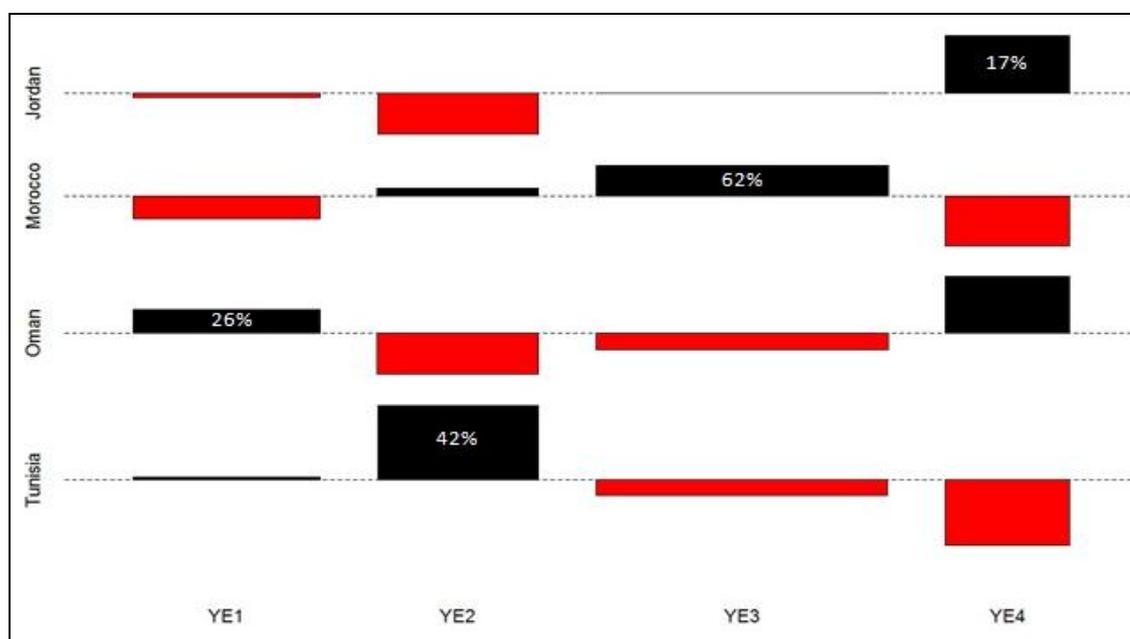


Figure 4.40: An association plot of the character Yaa at the end

Table 4.65 shows some of the handwriting examples with the actual shapes of the most associated character forms.

Table 4.65: Actual letter shapes of the character Yaa at the end

Country	Form	Actual Shape
Jordan	YE4	
Morocco	YE3	
Oman	YE1	
Tunisia	YE2	

K. Word Lam Alif (LA) لا

The word Lam Alif consists of a combination of two characters, “Lam” (ل) and “Alif” (ا). This word is written such that the character Alif cuts into the character Lam. Additionally, Lam Alif is considered a standalone word, as opposed to being a character and is always written the same regardless of where it is written.

The criteria used are based on whether this word was written as a single stroke or two strokes. The single stroke is defined as when the character Alif cuts across Lam forming either a circle or a triangle at the bottom and has one start and one end. Whereas the two strokes form is defined as when the two characters were written in two separate strokes forming a curve, a triangle, or either vertical or angled line at the bottom with or without crossing over.

Initially, analysis of the handwriting samples identified six different forms, as shown in Tables 4.66.

Table 4.66: Different forms of the word Lam Alif

Form	Shape	Description
LA1		1 stroke and cross with a circle
LA2		1 stroke and cross with triangle
LA3		2 strokes and cross with curve
LA4		2 strokes and cross with triangle
LA5		2 strokes without cross and vertical line
LA6		2 strokes without cross and angled line

Figure 4.41 shows the association of the word Lam Alif and shows that can be used to indicate that a writer was from Jordan (where form 5 was predominant), from Morocco (where form 3 was predominant), from Oman (where form 2 was predominant) or from Tunisia (where form 6 was predominant).

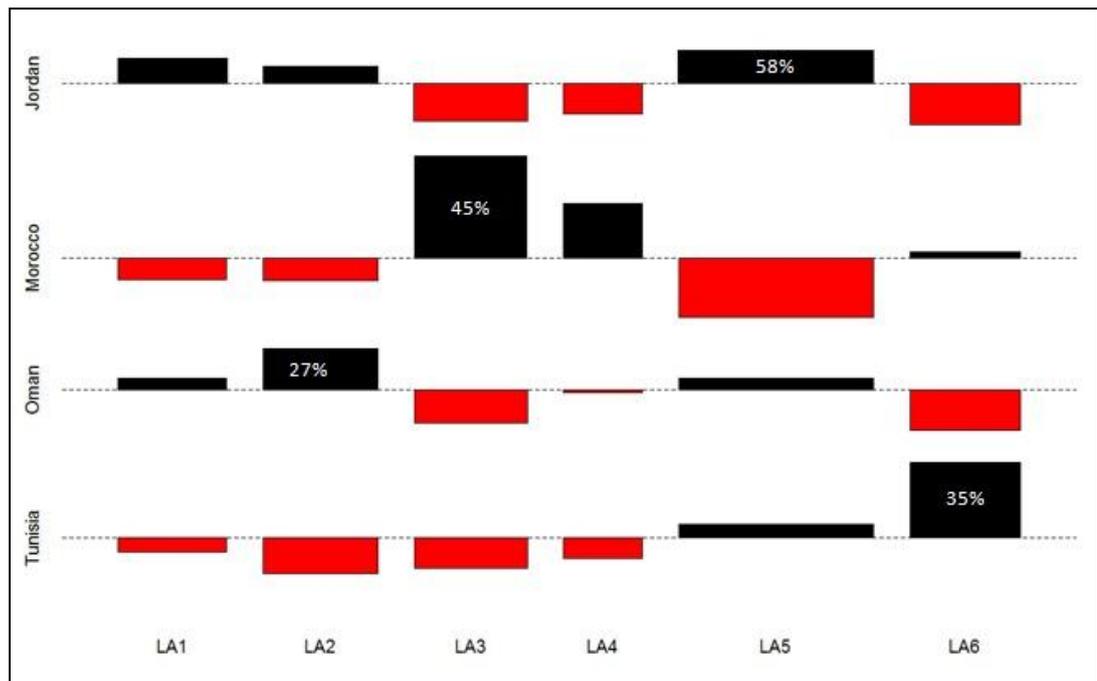


Figure 4.41: An association plot of the word Lam Alif.

Table 4.67 shows some of the handwriting examples with the actual shapes of the most associated forms.

Table 4.67: Actual shapes of the word Lam Alif

Country	Form	Actual Shape
Jordan	LA5	
Morocco	LA3	
Oman	LA2	
Tunisia	LA6	

4.3.2 Correspondence analysis

A correspondence analysis was conducted which resulted in a graphical plot of data obtained from the handwriting samples. This plot, known as an ordination, was used in order to illustrate whether any groupings were present in the data on the basis of the nationality or region of the participants. Samples which were more similar were plotted closer together according to a mathematically derived 'dissimilarity distance', so, those that were more dissimilar were plotted further apart. This analysis, therefore, also serves to graphically illustrate the extent of the variation present among participants within each of the four nationalities, as well as between these nationalities.

Figure 4.42 presents the results of this analysis. As shown, clear distinctions are evident between participants from Jordan (shown in red), Morocco (shown in green), Oman (shown in blue), and Tunisia (shown in purple). While groupings are shown on the basis of nationality, it is also clear that a fair degree of variation in handwriting within each of the four nationalities of the participant. It is also clear from the figure that there is a greater degree of similarity present in handwriting samples among participants from Jordan and Oman, representing the eastern region of the Arab world, as well as among participants from Morocco and Tunisia, representing the Western Region of the Arab world. While there is overlap, it is clear to see some distinction between much of the data from the Western and Eastern Arab Regions. Additionally, it is also notable that there is a greater degree of overlap in the data among participants from the Eastern Region of the Arab world as compared with data among participants from the Western Region. Dispersion in the data, representing within-group variance, was also shown to be smaller in the cases

of both Jordan and Oman, as compared with Morocco and Tunisia. In summary, irrespective of the overlap, the results of this analysis clearly indicate some distinct separations between the handwriting data on the basis of the region and nationality of the participant.

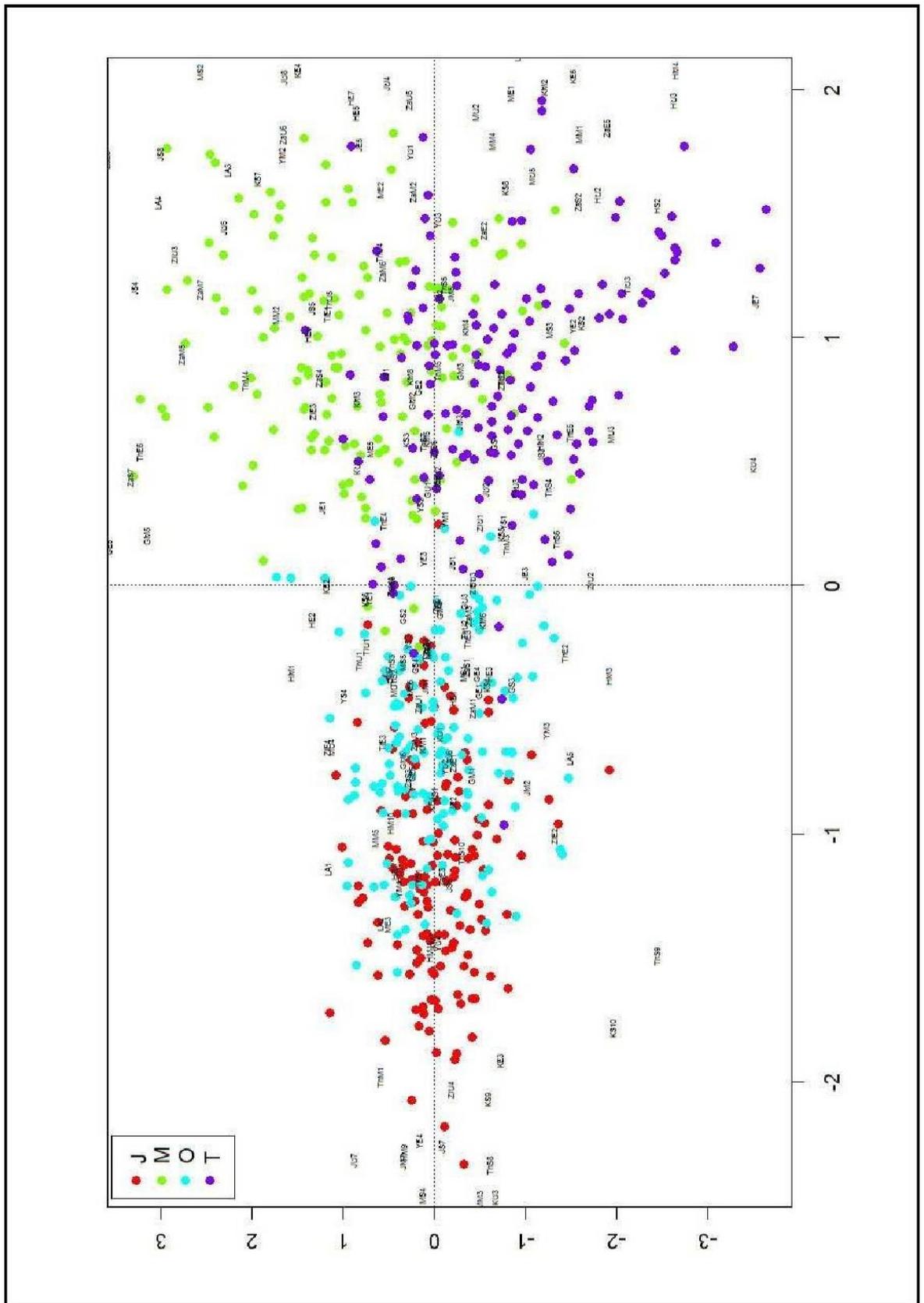


Figure 4.42: the Correspondence analysis plot illustrates the similarities and differences in handwriting based on the nationality of the participants. Note that participants from Jordan and Oman show greater similarities compared to between Morocco and Tunisia. There are also a strong regional and national variations.

4.3.3 ANOSIM (Analysis of Similarity)

An ANOSIM analysis was conducted in order to compare within-country and between-countries dissimilarities. The ANOSIM result was found to support the pattern seen in the correspondence analysis plot that the handwriting samples can be grouped according to country, and these groups are significantly dissimilar (ANOSIM $R = 0.321$, $p < 0.0002$, 1000 permutations).

4.3.4 Tree analysis

A tree analysis was conducted in order to determine whether the data obtained from character forms for each character could be used in order to predict the region or nationality of the writer in which he or she was taught to write, or to exclude him if the handwriting under examination does not contain the character forms determined by the test. Given that handwriting samples were only obtained from four countries, it is tempting to say that in the following descriptions, an indication of nationality only applies to these countries. Moreover, it is not possible to comment as to whether the samples could have been written by people in other countries that do not form part of this study.

As illustrated in the diagram produced by the tree test, with some character forms (Figure 4.43), the nationality of a writer or region could be predicted based upon these data. For example, if the character forms HS1 (Haa Start Form1), JS7 (Jeem Start Form7) and MS3 (Meem Start Form3) exist in the Arabic handwriting under examination, it can be stated from observation in this study that the writer could more likely be an Omani National. In contrast, if the character form HS1 does not exist in the questioned handwriting, it could result in an indication that it was not written by a Jordanian National.

The value 0.5 in the figure below is the mid point between 0 (absent) and 1 (present) which give rise to the dichotomy. The right branch represent the presence and the left branch the absence of the character form. The letters in the figure indicate the actual character followed by the position followed by the number of the character form, as mentioned above.

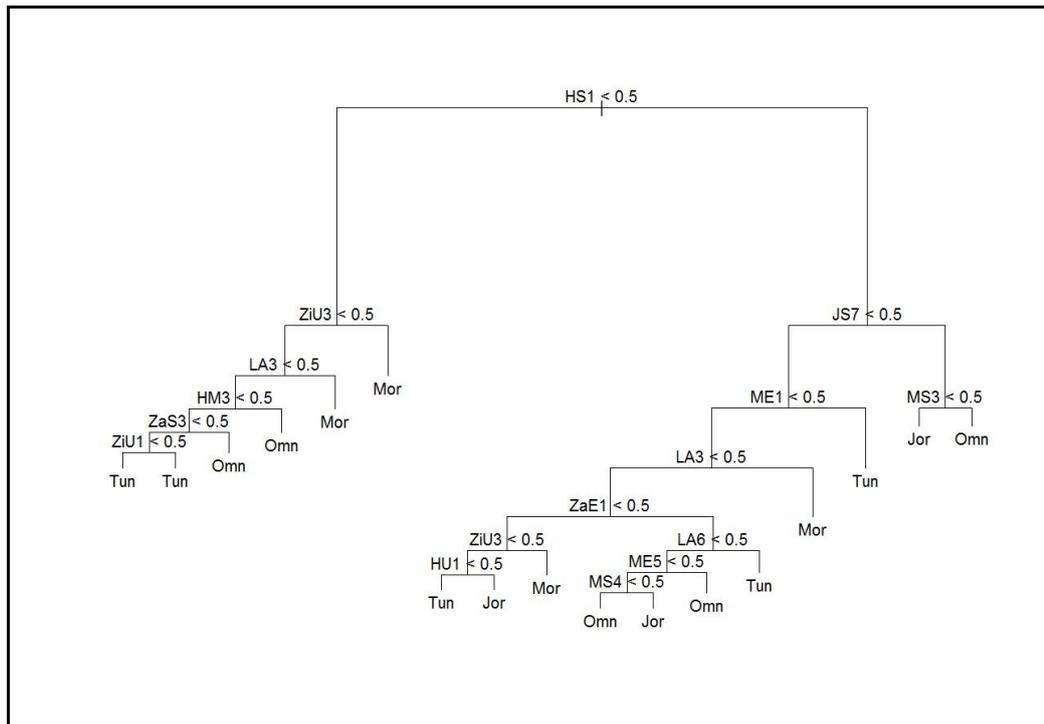


Figure 4.43: Plot obtained from tree analysis

On the basis of tree analysis, 2 x 2 and 4 x 4 contingency tables were created in order to assess the accuracy of the region and nationality identification, respectively. The tables compared actual country with predicted country based upon the tree analysis classification. From this, the accuracy of the regional identification was found to be 94% (Table 4.68) and the accuracy of the nationality identification as 71% (Table 4.69).

Table 4.68: Results of 2x2 for regional identification. Data are mean

Regions		Predicted nationality	
		Jordan and Oman	Morocco and Tunisia
Actual nationality	Jordan and Oman	274	26
	Morocco and Tunisia	12	288
Accuracy		95 %	

Table 4.69: Results of 4x4 for nationality identification. Data are mean

Country		Predicted nationality			
		Jordan	Morocco	Oman	Tunisia
Actual nationality	Jordan	98	2	47	3
	Morocco	5	101	5	39
	Oman	40	9	92	9
	Tunisia	7	11	7	125
Accuracy		71%			

4.3.5 Other variables

In addition to using country and region as explanatory variables, the same analyses were performed to see if gender, education or handedness, or combinations of these with country produced significant R results. In no case was the relationship stronger than with country alone (Table 4.70). Gender was the only other single variable to produce a significant R result with ANOSIM, but produced only 66% accuracy using the tree classification and only 40% accuracy when the eight combinations of country and gender were considered.

Table 4.70: Results of statistical analyses using different variables. * $p < 0.001$

Sr No	Variable	ANOSIM		Tree
		Statistic R	p-value	Accuracy
1	Country	0.321	<0.001*	0.71
2	Two regions – Eastern (Jordan and Oman) Western (Morocco and Tunisia)	0.3709	<0.001*	0.94
3	One region (Eastern) & 2 countries (M and T)	0.4765	<0.001*	0.87
4	One region (Western) & 2 countries (J and O)	0.1758	<0.001*	0.83
5	Gender	0.0095	<0.001*	0.66
6	Age	0.021	0.097	0.58
7	Handedness	-0.005	0.567	0.91
8	Education	-0.0015	0.550	0.50
9	Country and Gender	0.2911	<0.001*	0.40
10	Country and Age	0.2826	<0.001*	0.39
11	Country and Handedness	0.3007	<0.001*	0.64
12	Country and Education	0.2318	<0.001*	0.35

4.3.6 Blind tests

Blind analysis strategies, designed to minimise the possibility of bias in experimental results, have become increasingly required for higher standards of analyses in recent years.

In addition to the tests carried out above, blind tests based on tree analysis classification were conducted on the samples. Two sets of samples were chosen for the tests. One set consisted of 100 samples from the 600 samples used for the study and the other set of 20 new samples from each country, totaling 80 samples, not considered earlier, were used. The tests were carried out to determine the accuracy of the results obtained in the tree analysis

and further to confirm the various criteria for the forms selected for each position of all the characters. In other words, the blind test was used to test the ability of the classification system to indicate nationality of handwriting samples..

Table 4.71 shows the results of the blind tests for both the sets of samples, for the national and regional level.

Table 4.71: Accuracy for blind tests

Sample	Accuracy	
	Regional	National
With existing samples	95 %	76 %
With new samples	95 %	83 %

4.4 Summary

This chapter served to present the results of the analyses conducted, both descriptive as well as inferential, for this study. The focus of all of these analyses revolves around the main aim of the study to determine whether and how it was possible to either establish or predict the region or nationality of an Arabic writer on the basis of his or her handwriting. Initially, a set of descriptive statistics served to present the similarities and differences in handwriting on the basis of region and nationality. The results of these analyses, overall, illustrated substantial differences in handwriting with the forms used for 10 characters and one word being the focus of these analyses. Inferential statistical tests were conducted in order to further test whether substantial differences could be found in handwriting style on the basis of nationality. These tests consisted of an association test with chi-squared analyses, correspondence analysis, analysis of similarity, a tree analysis and blind tests. All of these tests serve to support the assertion that either the region or nationality of an individual writing in Arabic can be predicted on the basis of the handwriting style.

CHAPTER 5

DISCUSSION

5.1 INTRODUCTION

The purpose of this chapter of this study is to reflect on the research described in the previous chapters, in order to critically assess the validity of the approach used, to consider how the results obtained are in keeping with, or differ from the findings of other comparable studies and thereby, suggest further research that can build upon the foundations laid in this study.

5.2 INFLUENCES ON HANDWRITING CLASS CHARACTERISTICS

The overall appearance of the handwriting, as stated in the Introduction chapter is generally influenced by many factors, particularly, the educational system (Hanna,1989), the role of the family during the education process of the child, frequency of writing in both daily activities and in employment of an individual (Vos, *et al.*, 2000). Similarly, both the experience and influence of the writing style originally used in learned system and the teaching method in which children are taught to construct and then join letters (Muehlberger, 1989), will help to focus on penmanship. This is particularly at the beginning of the education journey. In addition, cultural influence could also play an important role in the general character of the handwriting, especially, between the connected geographical countries. The cultural effects on handwriting could result from the historical relations, people moving from one place to another (migration), colonisation or different languages being used within one single country (Ellen, 1997).

Previous studies have shown that for a given writing system, national or regional variations can occur. In 1989 Muehlberger studied the handwriting of Hispanics who were born in Latin America and who were living in the USA was

able to identify common features such as embellishment, pen-lifts, variety of forms and movement. These features were found to occur as a result of the influence of the used writing system (Muehlberger, 1989). In 2005, Cheng *et al* studied 154 English handwriting samples of the three racial groups including Chinese, Malays and Indians in Singapore. Six class characteristics were identified including letter designs, letter spacing and pen-lifts. The occurrence of these features could be attributed to the habitual influence of the native language (Cheng *et al.*, 2005). Recently, in the investigations conducted by Turnbull *et al* (2010) on the class characteristics of 106 samples of Polish people writing in English, the authors identified 34 features and observed the influence of the taught writing style in Polish adults' handwritings. They concluded that the influence of the copybook in the class characteristics may be due to the use of a single copybook pattern in Poland and penmanship in early education. They could identify several class characteristics, examples of which are that the letter A is starting with upstroke, b is written as a 6, and l written as a J and G written with a long tail. Also, an investigation was carried out by Katsaridou (2009) on the class characteristics in the English handwriting of Greek people, in which she used 100 samples and identified 40 class characteristics. In her study she determined whether individuals had been educated in the UK or in their native country. Some of the features that were determined include writing 'a' as an alpha, 'b' resembled the Greek letter beta, 'm' resembles the shape of the letter w and 'r' resembles the shape of the letter 'z'. Turner *et al* in 2008 looked at 37 samples and studied 19 features and found several changes in class characteristics of Gurumukhi handwriting between first generation and second generation of Punjabi population. Examples of these characteristics include the script type, letters size and angularity of strokes. As

stated by the authors, many factors could contribute to the differences between the first and second generations such as teaching system, the way handwriting is taught at school and the influence of the native language (Turner *et al.*, 2008).

As indicated in the Introduction chapter, handwriting is a complex process, since many factors are involved in its development and execution, hence justifying the complexity of such activity. For instance, as Huber and Headrick (1999) stated; writing is in part, culture dependent, and cultures differ with locals and undergo constant change. The evidence for this dependence is visible in class, system, or national characteristics. These factors might affect people learning the same script but in different countries and hence producing different handwriting features, thereby, producing regional and national variation. This was confirmed by results obtained from this study which is in line with what the above mentioned studies have concluded. Both findings support the hypothesis that people taught the same script in different places do write in different ways. However, this is not always the case, since people of different geographical areas would produce at least some similar common features when there are no potential reasons to write differently, particularly when they were taught to write from a single copybook style and practising the same teaching methods (Harris,1958). This is in agreement with what Muehlberger in 1989 mentioned, “The influence of the writing system will result in handwriting characteristics prevalent among writers who studied that particular system”.

This study clearly shows that the degrees of difference between the four countries studied are not the same. Inter-region differences were clearly

greater than intra-region differences. For example, Jordan differed more from Morocco and Tunisia than it did from Oman. This provides some support for either geographical or cultural influences on the handwriting features which could have resulted due to colonization. Morocco and Tunisia have both experienced considerable colonial influence from France whereas Jordan and Oman have not. Whilst this study has not found any obvious colonial influence in the characters of the alphabet, further studies involving the influence of colonisation in Arabic handwriting might bring to light that such influence could be a factor in the differences seen. However, this influence is clearly evident in the use of numerals in the two regions. In the Western Region, despite the copybooks using the Indian numerals, Morocco and Tunisia, tend to use the Arabic numerals which could be attributed to colonisation effects, whereas, in the Eastern Region, Oman and Jordan continue to use the Indian numerals. There are no known studies that have been carried out to prove that there have been any influences in the writing system in the Western part of the Arab world due to the presence of a foreign influence. Also, with increasing mobility of people from one place to another, this may see a reduction in any colonial influence and it could be expected that these differences in the writing of younger people may be less evident.

It is also possible that the cultural influences could be a factor justifying the differences between the two regions due to the geographical distances between the countries (Morocco and Tunisia are closer to each other while Jordan is comparatively closer to Oman than Morocco and Tunisia). A future study of other countries, such as Sudan or Egypt, which have had a considerable influence of Western powers from Great Britain, Portugal and

France and are geographically separated from the four countries, could be considered in order to explain the cultural influences.

Also, many other factors, such as, the movement of people between countries, gender, age, handedness, illness and family could alter the class characteristics and hence, cause changes in the findings. As a result, these considerations must be taken into account by Forensic Document Examiners in order to avoid any misleading conclusion while identifying the nationality of the writer.

5.3 COMPARISON OF FINDINGS TO THAT OF OTHER WORK

Keeping in mind the objectives, this study aimed to identify class characteristics in Arabic handwriting and establish whether distinctive features are more common to the handwriting of writers in four different countries of the Arab world.

The size of this study was of 600 samples and each of the ten characters and one word selected were examined in four different positions, resulting in eight characters being analysed 2400 times in four positions, two characters 1200 times in two positions and one word 600 times in one position. In comparison, in the other researches mentioned in this chapter, the sizes of the handwriting samples analysed were relatively small, since, the largest one was 154. The number of the class characteristics identified within those researches was ranging from 6 to 40, whereas this study was conducted on 221 class characteristics. In addition, the type and number of the statistical methods used by these other studies were; Turner (2008) used chi- square test, Katsaridou (2009) used three different statistical tests which were detrended correspondence analysis (DCA), analysis of similarity (ANOSIM) using

ordination in “R” and the proportion test, Turnbull (2010) used chi-square and Cheng (2005) used two-by-three chi-square and two-by-two chi-square. None of these studies had used association test or tree test.

The findings of this study are in agreement with the results of the above mentioned studies and confirm that class characteristics could be used to identify the nationality of a writer. However, most of these studies were concerned only in class characteristics of the English handwriting whereas, this study was conducted on the class characteristics of Arabic handwriting and no other research is known to have been conducted using Arabic handwriting samples.

Most of these studies focused on the presence of common class characteristics that could lead to possible identification of an individual's country of origin from a handwriting sample. The majority of them investigated the influence of the taught writing style of the mother languages in the handwriting of a foreign language (Jasuja, *et al.*, 1996). In other words, these studies investigated the presence of any similarities with the letter patterns of the native language in the handwriting of the foreign language, for example whether, the handwriting of Greek people writing in English presents similarities with the letters of the Greek alphabet. Some knowledge of other scripts with regard to the formation of their alphabets, and ways in which letters are connected, becomes useful when such scripts are the primary language, since features of this primary language may be reflected in writing in a second language (Singh and Saxena, 1994).

The usefulness of the outcome of this study was confirmed by the statistics, as detailed in the results chapter, which provide a strong evidence

that clear differences exist in handwriting style on the basis of the region or nationality of the participants. This also was evident from the test of significance, suggesting that region or nationality may potentially be predicted using Arabic handwriting data. The occurrence of common features in one region or one country and not in the others is of evidential value for the Forensic Document Examiner as it could lead to the identification of the place in which the writer was taught to write (Berthold and Wooton, 1998). For example, when character “Kaf”, written in the middle of a word (KM7), was found to be more common in Jordan, whereas, when character “Zai”, written as unconnected (ZiU3) was found to be more common in Morocco.

5.4 CLASSIFICATION SYSTEM

One of the main objectives of this study was to design a classification system to serve as a guide for the Forensic Document Examiner. Such a classification system was not addressed in any of the studies mentioned earlier in this chapter, nor are there any published studies focusing on Arabic handwriting in the context of determining regional or national characteristics. The ability to recognise and differentiate characteristics common to a particular group of writers from those specific to one individual is of paramount importance to the examiner of questioned documents (Muehlberger, 1989).

The classification scheme will enable document examiners to determine which features in a sample of handwriting might be regional or national features and hence give appropriate evidential weight to them in casework, unlike in the other studies where such schemes have not been developed (Cheng, *et al.*, 2005). Due to the focus on predictive power in relation to this study, a tree analysis was chosen over a cluster analysis, which focuses more strongly on

clustering cases and less strongly on predictive power, with the results of this analysis indicating how the data (the handwriting class characteristics in the case) could be used in order to predict region or nationality of the writer. In fact, classification tree analysis is considered by many researchers to be optimal as an exploratory technique, and was preferred in this study (Hill and Lewiski, 2006).

Using this system, a Forensic Document Examiner could identify some features that are in line with the results in this study and hence could use them to narrow the search and eventually could lead to an identification of a writer's region or nationality with accuracy up to 95% for the former and 83% for the latter, as stated in the results chapter. This reflects the reliability and usefulness of such a system; however, this is only true when the document under consideration has the same character forms identified in this study.

Table 5.1 shows typical example of used features in tree analysis. For example, if the character forms HS1 (Haa start Form1), JS7 (Jeem start Form7) and MS3 (Meem start Form3) and they exist in the Arabic handwriting under examination, application of the results of this study would identify that the writer is highly likely to be an Omani National. In contrast, if the character form HS1 does not exist in the questioned handwriting, it could result in a possible elimination of a Jordanian National.

Using handwriting as an approach for such identification is considered to be a breakthrough in the forensic sciences community which could now provide more pro-active support to an investigation (Harris, 1996).

Table 5.1: Scheme of commonly used features – tree analysis
(in order of appearance in tree diagram)

Sr. No.	Form	Feature	Description
1	HS1		Character Haa at the start of the word
2	JS7		Character Jeem at the start of the word
3	ME1		Character Meem at the end of the word
4	MS3		Character Meem at the start of the word
5	LA3		Lam Alif
6	Za1		Character Za at the end of the word
7	LA6		Lam Alif
8	ZiU3		Character Zai unconnected
9	HU1		Character Haa unconnected
10	HM3		Character Haa at the middle of the word
11	Za3		Character Za at the start of the word
12	ZiU		Character Zai unconnected

5.5 METHODS USED

As mentioned in the methods chapter, a number of steps were followed to extract the class characteristics from each of the samples from the four countries. Various steps of the process included working both manually and on a computer system. Manual procedures included the identification of the characters from the samples, scanning them and then studying the shape on the computer screen either as it was or by enlarging the character which involved drawing artificial boundaries for each of the sample studied. Extreme care has been taken and a high level of consistency was maintained while performing this procedure such as scoring all the samples on the basis of the

various criteria chosen for each character in all positions and extracting, recording and tabulating the obtained data continually by using excel sheets. This was done to ensure that no errors are introduced in preparing for the analyses.

It is not necessary for the Forensic Document Examiner to be able to read and write a script of foreign language in order to make an examination, as long as the examiner follows the scientific principles of handwriting comparison with the aid of one who is knowledgeable in the language (Muehlberge *et al.*, 1977). However, in most cases, once certain characters of the text are identified for examination, the required shapes could be examined with minimum awareness of the scoring scheme.

5.5.1 General characteristics of the participants

The choice of participants for obtaining the samples for the analysis was based primarily on two factors. The first being that they be in the age group of eighteen to about seventy. This is to ascertain that each participant has his own independent writing personality which starts at the age of eighteen as the handwriting features become fixed and to avoid any possible aging symptoms which normally begins after the age of seventy. Moreover, this period covers the writeres of the most related cases received for examination (Kapoor, *et al.*, 1985). The second factor being that they have certain level of basic education. These were of importance in order to ensure that the participants are skillful, more consistent in their handwriting and of less variation (Huber and Headrick, 1999). Though the selection of such participants could be considered to have been done randomly within the parts that could be reached in each country, since no conscious decision was made to choose a particular group of people

and hence, there are no known biases in the samples. The variations in the geographical location, age, gender, handedness and level of education indicate that the samples are random. However, certain practicalities, such as, being not able to have a complete representation from all parts of each country, could affect the results, especially if there are any more localised handwriting habits that have not been picked up in this study. Certain other considerations such as the selection of participants based only on occupations, for example doctors or teachers, could produce varying results. Other choices such as, study of handwriting samples of non Arabic nationals could also produce results differently. However, the four countries selected in this study, have a fairly high level of literacy as shown in the Table 5.2 and hence, it can be considered that the writers of the samples have a good education background.

Table 5.2: International literacy rate as published by UNESCO
<http://www.uis.unesco.org/literacy/Pages/adult-youth-literacy-data-viz.aspx>

Country	Literacy Rate (in %)
Jordan	92.6
Morocco	56.1
Oman	86.6
Tunisia	77.6

As mentioned in earlier chapters, the samples were obtained from only four countries of a total of 22 Arab countries, which could lead to an argument that the samples are not representative of all the Arab population. However, with the resources available and the fact that this study is being conducted by an individual in a specific time frame, making it practically difficult to address all the twenty two countries, it could be considered that the samples finally selected for the study are a good representation of the Eastern and the Western Arab worlds. Within the countries and regions studied in this investigation,

further research could be carried out to determine whether other combinations of countries also show similar distinctive national characteristics. Further, regional differences might become clearer and cultural or other explanations can be better explored. However, given regional differences are greater than national differences, it could be hypothesised that certain countries with very close cultural, historical and geographical connections might not show a national difference between them. This could be investigated in a new study which might show, for instance, that Gulf states are more similar to each other, such as Saudi Arabia to be more like Oman and United Arab Emirates and could also show that North African Countries are more similar to each other for example Algeria to be more like Morocco and Libya. However, since Egypt has different cultural, historical and with weak geographical connections to both Gulf and North African regions, future study could reveal more differences.

The author was very keen that the samples were taken in a normal situation such as writing while being seated, writing in normal speed and using the normal hand; so that the participants produce handwriting with a normal variation. This was considered to be important as it would produce the most natural handwriting features, which would assist in obtaining the best results. The obtained samples have all been considered to be natural writing of the participants, as there is no obvious reason for a disguised writing. Whereas, in a situation of a real casework involving a requested handwriting, it is important to determine whether the writing is natural or otherwise, as there would be sufficient reasons to produce a disguised handwriting. As such participants were requested to copy the passage by following the instructions combined with a distributed questionnaire as mentioned in the methods chapter. These instructions were believed to provide a good environment during the sampling

process. Also, certain motivational factors such as to provide a free copy of the thesis documents after the successful completion of the study to those who requested for it and specific compensations were introduced in order to obtain the best samples as required for the study. In other words, all efforts and care were taken and exercised in order to minimise any non-natural elements by using familiar materials in a comfortable environment.

The text for producing the samples has been carefully selected by the author who is highly proficient with the Arabic language and its alphabets. It has been ensured that all the Arabic characters are represented in all four positions. This procedure was followed to ensure that the handwriting samples were comprehensive and to achieve the aim of evaluating the complete range of variations between the four chosen countries in terms of the forms or styles of letters.

5.5.2 The selection of characters

Characters were chosen in this study such that they represent most of the complex characters of the Arabic alphabets, both those that form a part of groups of characters and those that have individual identity of their own. Of the ten characters and one word considered, some of the characters such as Thaa, Thal, Zai and the word Lam Alif were easier to score compared to the other seven characters, primarily because of the complexity of the shapes of the characters. The complexity of the characters, in general, would determine the possibility of obtaining wider variation. The more complex the characters, the better would be the results. Care has been taken to select such complex characters from among the characters with similar shapes in order to ascertain that it covers all the possible shapes that the particular group of characters

could produce. Any character has the potential to show national variation, but complex characters, simply because they are more complicated in their structure, have the greatest likelihood of showing national variations. This would invite future study of the simpler characters to see whether national characteristics are indeed most likely to be found in less complex letter structures. The study of such characters could add more value for forensic investigation of the questioned document because they may show additional differences or individual characteristics that could help in identification of the region or the nationality of the writer.

The reliability of differences in feature use will vary depending on a number of factors. In an ideal situation, the amount of text that is being studied would be sufficient to enable a full examination of the many possible letter forms. But in reality, the amount of text and its content is not controlled, particularly when a disputed document is the focus of the examination. This may then constrain how many features can be categorised and this in turn will affect the confidence with which the nationality of the writer can be determined. For instance, in a case where the document under examination only contains some character forms identified in this study and if they were common in each of the four countries, such as character Ghayn when written unconnected (JU1), it is less likely for Forensic Document Examiner would be able to identify the region or country of origin in which the writer was taught to write (Masson, 1988). However, some other features are distinctive and of discriminative power and hence indicative of identification of the region regardless of the amount of text available. An example of such a feature is the character Haa when written at the start of a word (HS1).

It would also be possible to consider the same or less complex structures of the characters shown in Table 5.3 which are not considered in this study. Features obtained from these characters could give additional value to the results in addition to the features of the characters selected. However, these characters were not included in the study primarily due to time limitations and also because some of the characters belong to a group of characters of similar structure out of which one of the similar characters has been selected for the study.

Table 5.3: Some of the characters not included in the study

Sr. No	Character	Shape
1	Alif	ا
2	Seen	س
3	Sheen	ش
4	Sad	ص
5	Dadh	ض
6	Faa	ف
7	Qaf	ق
8	Lam	ل
9	Waw	و

This study was also limited by practical considerations, particularly being able to establish good, reliable contacts in stable countries which could mean that a full picture of national variation has not been created. Further study of other countries would create a more fine-grained atlas of national variability. Such an atlas might also assist in determining the causes of national variability (Cha, *et al.*, 2005). On the basis of the four countries examined in this study a number of possibilities suggest themselves.

In order to make the scoring of features as precise as possible, the different categories were devised so as to be easy to identify and therefore

could be classified reliably. These were classified based on the way the characters are written in the four positions.

The criteria used are simple but they produce a sufficient number of shapes of the considered characters in various positions and hence, cover the various possible class characteristics and in turn establish a classification scheme that could be used to predict the region or nationality of the writer. However, Arabic is written in a cursive manner and most of the characters have complex structure; future study could use other criteria such as those of the character Sheen (ش) which could be written in two different styles; Naskh and Riqua. Another example is the joining points of the characters with its adjacent characters, especially when written as part of a word like character Meem (م) when joined with character Ha (ح) in the word (محمد). It is possible that these are likely to produce more national features and could obtain additional results.

Throughout the study, handwriting variation within an individual was not considered. This is because in many cases, the handwriting sample contained only one example of a character analysed, so no appreciation of variation was possible. Where more than one example of a character did exist in a sample, in every case there was only subtle variation which was not sufficient to be classified as a different form of the character. Thus, each character was classified as a single form for each handwriting sample.

Even though the focus of this research was to study the possibility of identifying the region or nationality of the participants, other variables such as gender, education and handedness were also statistically tested. However, the statistical results using variables were not encouraging for example prediction of gender was performed with only 66% accuracy. This result is in agreement with

results obtained from other studies on the influence of gender in handwriting having produced accuracy in the range of 70% as mentioned by Alkahtani and Platt (2011).

5.5.3 Statisticla Analysis

Finally, for the sake of minimizing the errors that could influence the outcome of this study, different statistical analyses were conducted which included both descriptive statistics as well as inferential statistical tests. These tests were used because the data are category (nominal) and can be summarised as frequencies, and hence, restricted the suite of possible statistcal methods and of those that chosen were most straightforward in their interpretation. However, future studies serving to expand upon this study and using this study as its base could utilise a larger set of inferential statistics, building upon the analyses conducted within this current study.

5.6 CONCLUSIONS

In summary, the study of Arabic handwriting undertaken in investigation reveals that a large variation is present among Arabic writers of different regions and nationalities. The study has also established a classification system through tree analysis, based on the determination of class characteristics in Arabic handwriting.

The results obtained are both valuable and useful, particularly to Forensic Document Examiners. These data could be implemented in practice in a situation where he or she is presented with a questioned document containing Arabic texts and the suspected author could have come from one of the four considered countries. Moreover, the present reuslts provide a path to a great

deal of evidence for an association between region and nationality and handwriting style, supporting the hypothesis that nationality might be predicted from handwriting style.

5.7 SCOPE FOR FUTURE STUDY

In order to get a more complete picture of regional and national variations in Arabic handwriting, further research on the other Arabic characters, dotting and joining strokes between characters could be conducted, with the inclusion of the other countries from different regions of the Arabic world. Moreover, variation in Arabic handwriting within an individual could be considered the focus for other future studies. There may be scope for further investigation using variables such as gender, age, education or combination of these variables, which were not explored in detail here.

REFERENCES

- Abboud, P. F., and McCarus, E. N. (1989). Elementary Modern Standard Arabic. Cambridge University Press, pp 3 -10.
- Al-dmour, A., and Abu zitar, R. (2007). Arabic writer identification based on hybrid spectral-statistical measures. *Journal of Experimental and Theoretical Artificial Intelligence*, 19, 307- 332.
- Alfard, EF. (1970). Disguised Handwriting: A Statistical Survey of How Handwriting is Most Frequently Disguised. *Journal of Forensic Science Society*, 15(4): 76-488.
- Alfayez M., Nizal H., Samarah M., Nagar A. (2008). *Dafter Al kitabah*. Ministry of Education, Jordan, pp 3 – 34.
- Al Haddad, A., White, P. C., and Cole, M.D. (2009). Examination of a Collection of Arabic Signatures. *Journal of the American Society of Questioned Document Examiners*, 12(1): 35-53.
- Alkahtani, AA., and Platt, AWG. (2010). A statistical study of the relative difficulty of freehand simulation of form, proportion, and line quality in Arabic signatures. *Science and Justice*, 50, 72–76.
- Alkahtani, AA., Platt, AWG. (2011). The Influence of Gender on Ability to Simulate Handwritten Signatures: A Study of Arabic Writers. *Journal of Forensic Sciences*, 56(4): 950- 953.
- Alkittani, A. (2009). *Dafter Al Khat*. Dar Al Thaqfah Le Nasher wa Tawziee. Dar Al Baidhga Morocco, pp 4–5.
- Al-Ohali, Y., Cheriet, M., and Suent, C. (2003). Databases for recognition of handwritten Arabic cheques. *Pattern Recognition*, 36, 111-121.
- Amin, A. (1998). Off – line Arabic Character Recognition: The State of the Art. *Pattern Recognition Society*, 31(5): 517- 530.
- Assaleh, K., Shanableh, T., and Hajji, H. (2009). Recognition of Handwritten Arabic alphabet via hand motion tracking. *Journal of the Franklin Institute*, 364, 175-189.
- Awaidah, S.M., Mahmoud, S.A. (2009). A multiple feature / resolution scheme to Arabic (Indian) numerals recognition using hidden Markov models. *Signal Processing*, 89, 1176-1184.
- Bakalla, M. H. (1984). *Arabic Culture through Its Language and Literature*. Kegan Paul International, London, pp 3–104.

- Baxendale, D., and Renshaw, ID. (1979). The Large Scale Searching of Handwriting Samples. *Journal of the Forensic Science Society*, 19(4): 245-251.
- Baxter, P. G. (1966). The distinction between "Graphology" and "Questioned Document Examination". *Medicine Science and the Law*, 6 (2): 75- 86.
- Behrendt, J. (1984). Alzheimer's disease and its effect on handwriting, *Journal of Forensic Sciences*, 29, 87–91.
- Bell, S.(2008). *Encyclopedia of Forensic Science*. (Rev. Edit.) Facts on file, New York, pp 73–74.
- Berthold, N. N. and Wooton, E. X. (1998). Class Characteristics of Latin American Hand Printing. *International Journal of Forensic Document Examiners*, 4(2): 134-151.
- Bishop, B. (1998). *A History of the Arabic Language Linguistics*, pp 450.
- Bonoti, F., Vlachos, F., and Metallidou P. (2005). Writing and drawing performance of school age children: Is there any relationship? *School Psychology International*, 26(2): 243-255.
- Bradley, A. J. (1986). Training program in questioned document examination. Denver, Colorado, (full text).
- Bray, J. R. and Curtis, J. T. (1957). An ordination of upland forest communities of southern Wisconsin. *Ecological Monographs*, 27, 325-349.
- Breiman, L., Friedman, J. H., Olshen, R. A., and Stone, C. J. (1984). *Classification and Regression Trees*. Wadsworth, Monterey, pp 20-250.
- Brown, FM. (1985). Teaching Handwriting in an English Inner-City Area. *Journal of Forensic Science Society*, 25(4):313-321.
- Burrow, P. (2004). *Arabic Handwriting Recognition*. (Master of Science Thesis), School of Information, University of Edinburgh, pp 15– 25.
- Cha S, Yoon S, Tappert CC. (2005). Handwriting copybook style identification for questioned document examination. *Journal of Forensic Document Examination*, 17, 1-14.
- Chartrel, and Vinter. (2008). The impact of spatio-temporal constraints on cursive letter handwriting in children *Learning and Instruction*, 18(6): 537-547.
- Cheng, N., Lee, G. K., Yap, B. S., Lee, L. T., Tan, S. K. and Tan, K. P.(2005), Investigation of Class Characteristics in English Handwriting of the Three Main Racial Groups: Chinese, Malay and Indian in Singapore, *Journal of Forensic Sciences*, 50(1): 177-184.

- Clarke, K.R., and Green, R.H. (1988). Statistical design and analysis for a 'biological effects' study. *Marine Ecology Progress Series*, 46, 213-226.
- Cohen, A. (1980), On the graphical display of the significant components in a two-way contingency table. *Communications in Statistics—Theory and Methods*, A9, 1025–1041.
- Conway, J. V. P. (1959). *Evidential Documents*, Charles Thomas, Springfield, LL, pp 38-40.
- Crown, DA. (1987). Practical Aspects of the Mengele Handwriting Examination. *Forensic Science Society*, 27(1):5-11.
- Davis, T., (2007). The Practice of Handwriting Identification. *Library; The Journal of the Bibliographical Society*, 8 (3):251-276.
- Directorate general of the curriculums development. (2011). Activities brochure in support of the book (my language characters). Ministry of education, Sultanate of Oman, Al-shurqiah Press, (full ext).
- Duncan, MI., and Gilbertson, B. (1983). Two Different Effects of Brain Cancer on Writing. *Journal of Forensic Science Society*, 23(2); pp 161-162.
- Eldridge, M.A., Nimmo-Smith, I., Wing, A.M. (1985). The Dependence Between Selected Categorical Measures of Cursive handwriting. *Journal of Forensic Science Society*, 25:217-231.
- Eldridge, MA., Nimmo-Smith, I., Wing, AM., and Totty, RN. (1984). "The Variability of selected Features in Cursive Handwriting: Categorical Measures". *Journal of the Forensic Science Society*, 24(3):179-219.
- Ellen, D. (1993). *The scientific examination of documents: Methods and techniques*. Chichester: Ellis Horwood Ltd, pp 8 – 23.
- Ellen, D. (1997). *The Scientific Examination of Documents: Methods and Techniques*, second ed., London: Taylor & Francis, pp 27–69.
- Finch, T. (1992). "Class Characteristics of Alphabetic Speed Writing Shorthand Systems" *Journal of Forensic Science*, 37(1):265-280.
- Foley, BG. (1979). "Handwriting Entry Research" *Journal of Forensic*, 24(2):503-509.
- Foley, R. G. (1979). The effect of Marijuana and Alcohol usage on handwriting, *Forensic Science International*, 14:159 – 164.
- Franks, JE., Davis, TR., Totty, RN., Hardcastle, RA. and Grove, DM. (1985). Variability of Stroke Direction between Left-and Right-handed Writers. *Journal of the Forensic Science Society*, 25(5):353-370.

Fromkin V. and Rodman R. (1998). *An Introduction to Language*. Harcourt Brace College Publishers, New York, pp 541- 553.

Graham, S. and Weintraub, N. (1996). A Review of Handwriting Research: Progress and Prospects from 1980 to 1994, *Educational Psychology Review*, 8(1): 7-87.

Goonetilleke, R. S., Hoffmann, E. R., Luximon, A. (2008). "Effects of pen design on drawing and writing performance" *Applied Ergonomics*, 40(2): 292– 301.

Greenacre, M., and Nenadic, O. (2010) ca: Simple, Multiple and Joint Correspondence Analysis. R package version 0.33. <http://CRAN.R-project.org/package=ca>, (full text).

Hanna, G. A. (1989). A Preliminary Classification of the Writing Elements of Chinese Characters, *Journal of Forensic Sciences*, 34(2): 439-448.

Hardcastle, RA. and Kemmenoe, D. (1990). A Computer Based System for the Classification of Handwriting on cheques: part 2 Cursive Handwriting. *Forensic Science Society*, 30,97-103.

Hardcastle, RA., Thornton, D. and Totty, RN. (1986). A Computer-based System for the Classification of Handwriting on Cheques. *Journal of Forensic Science Society*, 26,383-392.

Harris, J. J. (1958). How much people write alike: a study of signatures, *Journal of Criminal Law, Criminology and Police Science*, 48 (6): 647–651.

Harris, J. S. (1996). Determining nationality from written speech: A preliminary report, *International Journal of Forensic Document Examiners*, 2(4): 300-325.

Harrison, WR. (1958). *Suspect Documents – Their Scientific Examination*. Eastern Press Ltd., London, pp 288- 348.

He, Z., You, X., Tang, YY. (2008). Writer Identification using global wavelet – based features. *Neurocomputing*, 71, 1832 – 1841.

Heinrich, J. G. (2003). *Benefits of Blind Analysis Techniques (1)*, University of Pennsylvania, pp 126 -135.

Hilton, O. (1969). "Consideration of the Writer's Health in Identifying Signatures and Detecting Forgery" *Journal of Forensic Science*, 14(2):157-165.

Hilton, O. (1983). "How Individual are Personal Writing Habits?" *Journal of Forensic Science*, 28 (3):683-685.

Hilton, O. (1993). *Scientific Examination of Questioned Documents* CRC Press London, pp 154-160.

Hilton, O. (1984). Effects of writing instruments on handwriting details. *Journal of Forensic Sciences*, 29 (1): 80-86.

- Hirschfeld, H.O. (1935). A connection between correlation and contingency, *Proceedings of the Cambridge Philosophical Society*, 31, 520-524.
- Holes, C. (1995). *Modern Arabic Structures, Functions and Varieties*. Longman Publishing, New York, pp 1- 38.
- Huber, RA., and Headrick, AM. (1999). "Handwriting Identification: Facts and Fundamentals". New York CRC Press, pp 11- 243.
- Jasuja, O., Komal and Singh, S.(1996). Examination of Gurumukhi script: a preliminary report, *Science and Justice*, 36, 9-13.
- Kandel, S., Soler, O., Valdois, S., and Gros, C.L. (2006). Graphemes as motor units in the acquisition of writing skills *Reading and writing Journal of Experimental Psychology: Human Perception and Performance*,19 313-337.
- Kapoor, JS. Kapoor, M., and Sharma, GP.(1985). Study of the form and extent of natural variation in genuine writings with age. *Journal Forensic Society*, 25,371-375.
- Katsaridou, N. (2009). *Class Characteristics in the English Handwriting of Greek People*. MSc. Thesis. The University of Central Lancashire - School of Forensic and Investigative Sciences, pp 9 - 46.
- Kelly, J., S., Lindblom, B. S. (2006). *Scientific Examination of Questioned Documents*, Second Edition, Taylor and Francis Group, pp 47 – 76.
- Kerr, L. K. and Taylor, L. R. (1992). Linguistic Evidence Indicative of Authorship by a Member of the Deaf Community, *Journal of Forensic Sciences*, 37(6): 1621-1632.
- Koppenhaver, K. M. (2007). *Forensic Document Examination – Principles and Practice*. Human Press, Totowa, New Jersey, pp 1-36.
- Lee, CD. and Abbey, RA. (1992)."Classification and Identification of Handwriting". D Appleton & co., New York, pp 5-110.
- Leung, SC. Chung, MWL. Tsui, CK., and Cheung, WL. (1987). A comparative approach to the examination of Chinese handwriting Part 2-Measurable parameters. *Journal of Forensic Science Society*, 27, 157 – 173.
- Leung, SC. Et al. (1993). A Comparative Approach to the Examination of Chinese Handwriting Part 5 – Qualitative Parameters. *Journal of Forensic Science Society*, 25 (4): 255- 267.
- Levinson, J. (2001). *Questioned Documents A lawyer's Handbook*. Academic press, London, pp 1- 57.

Li, C-K., Poon, N-I., Fung, W-K., and Yang, C-t. (2005)." Individuality of Handwritten Arabic Numerals in Local Population". Journal of Forensic Sciences, 50(1):1-7.

Longstaff, and Heath. (2003). The influence of motor system degradation on the control of handwriting movements: a dynamical systems analysis. Human Movement Science, 22, 91-110.

Manfredi, M. L. Cha. S-H., Yoon, S., and Tappert, CC.(2005). "Handwriting Copybook Style of Pseudo-On line Data", (full text).

Masson, J. F. (1998). A Study of the Handwriting of Adolescents, Journal of Forensic Sciences, 33(1): 167-175.

McAlexander, TV; Beck, J; and Dick, RM (1991). The Standardization of Handwriting Opinion Terminology. Journal of Forensic Sciences, 36(2): 311 – 318.

McAlexander, TV. (1997). Assigning Weight to Handwriting Differences for Elimination Purposes, International Journal of Forensic Document Examiners, 3(1): 4-7.

McClary, CR. (1997). A Study of Baseline Alignment in Signatures and Handwritten Sentences. International Journal of Forensic Document Examines, 3(1):35-44.

Meulenbroek, R. G.J., and Thomassen, A. J.W.M. (1991). Stroke-direction preferences in drawing and handwriting. Human Movement Science, 10, 247-270..

Miller, JT.(1972). "Departure from Handwriting System". Journal of Forensic Science, 17(1):107-123.

Morgan, M. and Zilly, P. (1991). Document Examinations of Handwriting with a Straightedge or a Writing Guide. Journal of Forensic Science, 36(2):470-479.

Morris, R. (2000). Forensic Handwriting Identification – Fundamental concepts and principles. Academic press, London,pp 1-175.

Muehlberge, RJ., Newman, KW., Regent, J. and Wichmann, JG. (1977). A Statistical Examination of Selected Handwriting Characteristics. Journal of Forensic Science, 22(1):206-215.

Muehlberger RJ. (1989). Class characteristics of Hispanic writing in the southeastern United States. J Forensic Society, 34(2):371–376.

Naftali, AI. (1984). Temporary changes in handwriting revealing mental attitudes and their Forensic Significance. Journal of Forensic Science Society, 24(4): 414.-421.

Naider-Steinhart, S., Katz-Leurer, M. (2007). Analysis of proximal and distal muscle activity during handwriting tasks, *American Journal of Occupational Therapy*, 4, 392-398.

Nassar, A. "Scientific Method of Forgery Detection in Questioned Documents" Unpublished, pp 1–42.

Osborn, A. O. (2010). *Questioned Documents: A study of Questioned Documents within an outline methods by which the facts may be discussed and shown*. The lawyer co-operative publishing Co., Rochester, New York, pp 168 – 235.

Othman, M. S. (1966). Notes in counterfeiting and Forgery and the scientific methods to detect them. *Cario, Egypt*, pp 29 – 56.

Peebles, EE., and Morris, GL. (1986). Genetic and environmental influences on graphological factors. *Behavior genetics*, 16 (6): 631 – 631.

Pervouchine, V. And Leedham, G. (2007). Extraction and analysis of forensic document examiner features used for writer identification. *Pattern Recognition*, 40, 1004-1013.

Peters, J. (2007). *Very Simple Arabic Script*, Stacey International. Reprinted by Oriental Press, Dubai, pp 13 – 47.

Plimmer, B., Reid, P., Blagojevic, R., Crossan, A., and Brewster, S. (2011). Signing on the tactile line: A multimodal system for teaching handwriting to blind children. *ACM Trans. Comput.-Hum.*,18(3): 235-244.

Ravindra, S. Goonetilleke, Errol, R. Hofimann, Ameersing Luximon (2009). Effect of pen design on drawing and writing performance. *Applied Ergonomics*, 40, 292 – 301.

Rihlaty, Al. Aula. Fe. (1998). *Alam Alhorooft Wa Al Kalimah Dar Alshabab Le nasher wa Al tawziee*. Tunisia, pp 5 – 26.

Ripley, B. (2010). *tree: Classification and regression trees*. R package version 1.0-28. <http://cran.R-project.org/package=tree>, May 2011, (full text).

Rosenblum, S., and Livneh-Zirinski, M. (2008). Handwriting process and product characteristics of children diagnosed with developmental coordination disorder. *Human Movement Science*, 27, 200-214.

Saferstein, R. (1995). *Criminalistics: An Introduction To Forensic Science*, Prentice Hall Regents, Englewood Cliffs, USA, pp 470 – 488.

Saferstein, R. (1982). *Forensic Science Handbook*, Prentice Hall Regents, Englewood Cliffs, USA, pp 678 – 693.

Saudek, R. (1933). Anonymous letters – a study in crime and handwriting. Methuen, London, pp 10 – 34.

Saudek, R. (1978). Experiments with handwriting: books for Professionals University Microfilms International, London, (full text).

Saxena, HM., and Singh, M. (1992). Classification of the Writing Elements in Devnagari Script. *Journal of Forensic Science Society*, 32(2):143-150.

Schuetzner, E. M. (1999). Class Characteristics of Hand Printing. *Journal of the American Society of Questioned Document Examiners*, 2(1):5-33.

Simner, ML. Smits-Englesman, BCM. (2000). The use of foreign copybook patterns to determine the country of origin of the author of a questioned document. *Journal of Forensic Document Examination*,13:45-51.

Singh, A. Gupta, SC., and Saxena, HM. (1994). Influence of the Primary Language and Idiosyncratic Features in Simple Forgeries. *Journal of Forensic Science Society*, 34:84-87.

Smart, JR. (1992). Teach Yourself Arabic – A Complete Course for Beginners. Hodder Headline, London, pp 5-21.

Srihari, S.N., Cha, S-H., Arora, H., and Lee, S. (2002). Individuality of handwriting *Journal of Forensic Science*, 47(4): 227-474.

Stangohr, G. (1971), Determination of Nationality from Handwriting *Journal of Forensic Sciences*, 16(3): 343-358.

Sung-Hyuk Cha, Sungsoo, Yoon, and Charles C. Tappert. Handwriting Copybook Style Identification for Questioned Document Examination. School of Computer Science and Information Systems, Pace University, pp 1-11.

Taroni, F., Marquis, R., Schmittbuhl, M., Biedermann, A., Thie´ry, A., and Bozza, S. (2012). The use of the likelihood ratio for evaluative and investigative purposes in comparative forensic handwriting examination. *Forensic Science International*, 214, 189–194.

Terri, DeYoung.(1999). History of the Arabic Language. <http://www.arabicstudies.edu/arabiclangrev.htm>, March 2010, (full text).

Totty, RN., and Hardcastle, RA. (1983). The Dependence of Slope of Handwriting upon the Sex and Handedness of the Writer. *Journal of Forensic Science Society*, 23(1) :237-240.

Totty, RN., Hardcastle, RA., and Pearson, J. (1987). Forensic Linguistics: the Determination of Authorship from Habits of Style. *Forensic Society*, 27(1):13-28.

Turnbull, S. J. (2010). Identification of the class characteristics in the handwriting of Poilsh people writing in English. *Journal of Forensic Sciences*, 55 (5): 1296- 1303.

Turner, I. J., Sidhu R. K., Love, J. M. (2008). A preliminary study investigating class characteristics in the Gurmukhi handwriting of 1st and 2nd generation Punjabis, *Science and Justice*, 48, 126–132.

UNESCO, (2011). International literacy rate. (<http://www.uis.unesco.org/literacy/Pages/adult-youth-literacy-data-viz.aspx>), November 2012, (Full text).

Van der Plaats, R. E., & Van Galen, G. P. (1991). Allographic variability in adult handwriting. *Human Movement Science*, 10(2-3): 291-300.

Van Dyck, Edward, A. (1894). *History of the Arabs and their Literature before and after the rise of Islam*. (Cairo, Egypt), (full text).

Van Dyck, Galen. (1991). Handwriting: issues for a psychomotor theory. *Human Movement Science*, 10, 165-191.

Vos, M. Strach, S. and Westwood, P. (2000). *Handwriting. Forensic Document Services*. Academia Press. Australia, (full text).

Walton, J. (1997). Handwriting changes due to aging and Parkinson's syndrome. *Forensic Science International*, 88, 197-214

Whiting, F. (1990). Inconclusive Opinions: Refuge of the Questioned Document Examiner. *Journal of Forensic Science*, 35(4): 938-946.

Wing, AM., and Nimmo-Smith, I. (1987). The Variability of Cursive Handwriting Measure Defined Along a Continuum: Letter Specificity. *Journal of the Forensic Science Society*, 27(5): 273-297.

Yank, J.R. (1991). Handwriting variations in individuals with MPD. *Dissociation*, 4(1): 2-12.

Ziviani, J. and Watson-Will, A. (1998), Writing speed and legibility of 7 - 14 - year-old school students using modern cursive script. *Australian Occupational Therapy Journal*, 45: 59–64.

Appendix 1
Questionnaire

Questionnaire

استبيان

Please fill up this questionnaire

الرجاء تعبئة هذا الاستبيان:

1. Name (Optional):

١. الإسم (اختياري):

2. Age:

٢. العمر: -----

3. Gender :

٣. الجنس :

أنثى (Female)

ذكر (Male)

4. Level of Education

٤. المستوى التعليمي:

5. Nationality (the country you belong to)

٥. الجنسية (البلد الأصلي المنتسب اليه):

6. Handedness

٦. اليد المستخدمة في الكتابة

كلاهما (Both hands)

اليسرى (Left)

اليمنى (Right)

7. Geographical Area you learned to write

٧. المنطقة التي تعلمت فيها الكتابة

Appendix 2

Instructions

Please follow up these instructions **carefully** while writing أثناء الكتابة بدقة أتباع التعليمات التالية بدقة

Instructions in English	التعليمات باللغة العربية
a) Use your normal hand that you use to write (right or left)	أ - استخدم اليد <u>المعتاد</u> الكتابة بها
b) Write in the normal speed you are used to writing	ب - أكتب بالسرعة <u>المعتادة</u> لديك
c) Use the same provided sheet	ت - اكتب على الأوراق <u>المسطرة</u> المرفقة
d) Don't bend the paper	ث - عدم <u>ثني</u> الورقة أو <u>طيها</u>
e) Write only one side of the paper	ج - أكتب على جانب <u>واحد</u> من الورقة
f) Use blue or black ball point pen only	ح - اكتب بقلم <u>جاف</u> أزرق أو أسود
g) Write your sample while you are sitting comfortably and when you are not likely to be disturbed	خ - اكتب وأنت في وضع <u>الجلوس</u> المريح (على طاولة وكرسي)
h) Write the whole text with the alphabets and numerals	د - أكتب <u>جميع</u> البيانات (الأحرف، الأرقام، والنص).
i) It is preferable to write by asking someone to dictate to you instead of looking to the text and copying.	ذ - يفضل الكتابة عن طريق <u>الإملاء</u> بدلا من النقل.

Appendix 3

Correspondence analysis plot

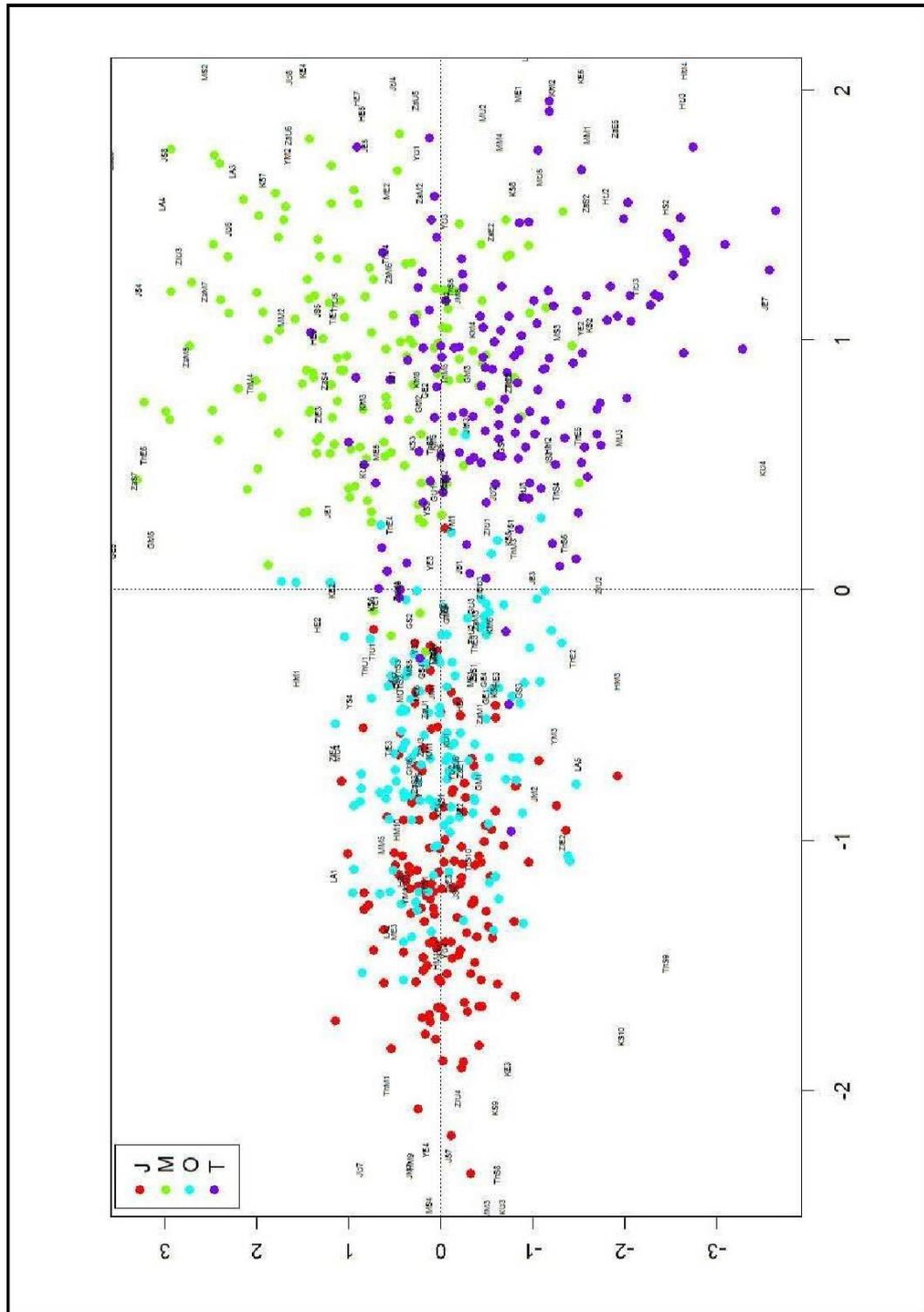


Figure 4.42: the Correspondence analysis plot illustrates the similarities and differences in handwriting based on the nationality of the participants. Note that participants from Jordan and Oman show greater similarities compared to between Morocco and Tunisia. There are also a strong regional and national variations.