

Devanagari handwriting primitives and their effect on acquisition

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Abstract

Since ancient times, across civilizations, various scripts have been developed and have continued to be in use even today. This proves that the practice to learn and write is ancient. However, evidences of scientific research on handwriting can be traced only since 19th century AD and most of it is Roman/Latin centric.

Surprisingly, in a multi-script country like India, no trace of scientific research has been found on the process of teaching and learning handwriting. Each script is unique and has different graphical and morphological aspects. Hence, it is necessary to study every script individually.

The skill of handwriting is acquired through regular and step-by-step practice. And it starts with learning some basic strokes. Traditionally, various learning aids also known as primers were used to teach handwriting. From those, the ones being used today were analysed. It was observed that, in those primers practice of basic strokes was missing. The only exception was a text book from first grade which mentioned 8 basic strokes. However, these basic strokes didn't seem to be of much relevance for a complex script like Devanagari.

How important are the basic strokes for handwriting acquisition, hasn't been researched yet. Therefore, to confirm the conventions, instructional theories of academicians were studied. In the context of skill acquisition, Jerome Bruner's concept of "Spiral Curriculum" emphasises on information being structured, so that complex ideas can be taught at a simplified level first, and then re-visited at more complex levels later. This supports our assumption about the need of handwriting primitives (basic strokes) in the process of handwriting acquisition.

Having established this, we then probe into understanding the sufficiency and efficacy of existing Devanagari basic strokes for the complex graphical nature of the complete script.

Further, we shed light upon what can be Devanagari's basic strokes and, how to extract them.

The session on extraction, was conducted with two groups of people. The first, with six random participants who were given general instructions to cull out the various basic strokes of Devanagari. The participants manually traced the various strokes from the given model sheet of letters. The second group comprised five expert participants who were given pointed instructions to perform the same task. Clustering these strokes as per form and movement similarity, led us to find primitives for Devanagari handwriting. The primitives were classified into ‘unidirectional’ and ‘multi-directional’.

In comparison to these, the strokes mentioned in the first grade book were found insufficient.

Now, to test the efficiency of these primitives, final experiment was designed. After conducting many pilots, two important aspects were finalised, the material used to conduct the experiment and the framing of appropriate subjects to test the material. This experiment was conducted in four stages namely- Treatment, Post-Test, Evaluation by jury and Statistical Analysis. As there was no established process to evaluate the letterforms, an indigenous evaluation sheet was designed for the evaluation of the Post-test by the jury. A pilot evaluation test was conducted to confirm the factors of evaluation for handwriting acquisition along with a measuring scale.

The results of statistical analysis of the jury evaluation proved that the basic stroke practice is effective for correct handwriting acquisition. Moreover, it was also proved that script specific practice is necessary for correct acquisition. The newly extracted Devanagari primitives for handwriting have shown significant impact on handwriting acquisition by new learners. The manual method for extracting handwriting primitives are proposed, which will surely help many other Indian scripts in the future.

Organisation of thesis

The entire thesis is divided into five chapters. It begins with Chapter 1, Introduction and closes with Chapter 5, Conclusion.

Chapter 1, Introduction explains the significance of handwriting in the present world scenario. Further, looking at the needs of today's generation, it identifies the research gap in context to handwriting acquisition and elaborates the scope of study in this domain. The chapter then concludes into research questions that guides our research enquiry into handwriting acquisition.

Chapter 2: Background study can be broadly divided into two parts. The first part orients with spoken and written language and the varying scripts systems of the world. It then proceeds with an elaborate study of the developmental process from letter recognition to handwriting acquisition. It studies the research in handwriting acquisition from 19th century done in context to Roman/Latin script and recent research conducted by Indians that helps to understand the approaches and their shortcomings. The second part orients with the details of the structure of Devanagari script from handwriting point of view. It incorporates survey of teaching/learning aids for Devanagari handwriting, closing with a detailed analysis of Devanagari handwriting primers which are widely used in current times. The insights thus received from these two parts reassure and clarify the research questions.

Chapter 3: Manual Extraction of Devanagari primitives is an exercise designed by taking hints from the learning and skill acquisition theories. This exercise is conducted in two separate parts, firstly on students pursuing graphic design and secondly on experts in the field of Typography and Calligraphy. Part one of the exercise was conducted by giving general instructions to the students on the manual extraction of Devanagari basic strokes. This exercise yielded the inventory of strokes separated from the basic set of Devanagari letters which enabled the clustering of uni-directional primitives. The insights from part one of the exercise helped to design specific sets of instructions to conduct similar enquiry on experts. The visual and stroke direction analysis of the data received as the outcome of part two resulted into multidirectional primitives. The compilation of strokes received from the two parts of

the exercise resulted into a set of primitives which justify the morphological complexity of Devanagari script for handwriting purposes.

Chapter 4: Validating the Extracted Primitives. The extracted Devanagari primitives were tested on first grade school children through experiments in order to validate their efficacy on handwriting acquisition. Series of pilot experiments lead to the detailed design of the final experiment, material, the age of the subjects, the experimental procedure and the evaluation process of the data. The final experiment had to be conducted twice. The second attempt of the experiment was made in a different state to clear the background threat of the subjects as realised in the first attempt. The data received from both these experiments were then analysed statistically by using ANOVA. The comparison of results showed significant level of correct acquisition in the group which practiced the extracted Devanagari primitives against the groups which practice the primitives present in the existed primers.

Chapter 5: Conclusion: In the final chapter we summarize the research work in form of major findings, present the significant contributions and discuss the future scope of the study.

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Glossary

Baseline Test - The test which allows uncovering the pre-requisites of the participants before they are sorted into groups. For example, with context to our Experiment No. 2 – Chapter 4, 1st standard school children were the subjects of experiment. Before dividing them into three different groups it was essential to conduct a baseline test which would make us aware about the acquisition level of handwriting. Base line Test is synonymous to Pre-test.

Treatment - Treatment is the stimulus given to the dependent variable. In context to this research, 10 minutes practice of conventional basic strokes, extracted Devanagari primitives, and complete letterform was the treatment given to the participants i.e. school children. (*Refer Page 88 Section 4.5 Table 4.3*)

Treatment Group - The group of participants which received a specific treatment are termed as treatment groups. For example, Group A received treatment of practicing conventional Devanagari basic strokes present in the school book. Group B received a treatment of practicing the extracted Devanagari primitives.

Post-Test - The test that is conducted after treatment to understand the effect of the treatment.

True Experiment - True experiment is a type of experimental design which is employed to establish a cause and effect relationship.

Background Threat - Background threat here means the undetected pre-requisite information of the participating students in context to the experiment. For example, in context to the experiments of our research enquiry, a few of the 1st standard English medium students were taught Devanagari script by their parents before enrolling them in school. This case is termed as parental intervention in educational research. Hence, this background information of the participating students misled the research in the first experiment while validating the effects of the extracted Devanagari primitives. Such undetected background fact of the student participating in the experiment is termed as background threat. (*Refer Section 4.6.8*)

Overall Proportion – Overall proportion here means the overall proportions of single letterforms. Handwritten letterform is made out of strokes and their

interrelated positions and sizes. This defines the overall proportion required for readability. (*Refer Section 4.5.4*)

Letterform Gravity – In Devanagari, a letterform is assumed to be standing on the imaginary horizontal baseline. The overall balance achieved by the letterform in relation to its baseline is termed as letterform gravity. (*Refer Section 4.5.4*)

Percent Differential - Percent differential is opinion of two different juries expressed through evaluation. Although the marking evaluations of the juries differ in numbers, their opinion expressed remains the same. For example, Jury 1 gave 6 marks to Group A, 8 marks to Groups B & 4 marks to Group C. On the other hand, Jury 2 gave 4 marks to group A, 6 marks to Group B & 2 marks to Group C. Both the juries gave Group B the highest marks and Group C the lowest and average medial marks to Group A. Thus both the juries consider Group B to be the best performer with Group A in second place and Group C at third even though the marks given by them differ numerically. (*Refer Section 4.6.6*)

Symmetrical Trend - Trend here means jury's opinion expressed after evaluation. Although, it is asymmetrical in numbers, the opinion that Group B is at the highest position, Group A is in the middle and Group C is at the bottom is symmetrical. This is termed as symmetrical trend. (*Refer Section 4.7.4*)

Chapter 1 Introduction

While teaching calligraphy and typography for almost two decades at UG level in Mumbai, a cosmopolitan city of a multi-script country, India, atypical change in students' Devanagari handwriting was found in the newer generations of typography class. This observation motivated us to probe into how Devanagari handwriting is acquired.

The term 'writing' has varied meanings in different contexts. This study is focused on the activity of writing by hand, especially, its acquisition. Before a letterform acquisition, its recognition is important for a learner. Learning handwriting begins at the age of five years when a child has already begun recognizing Akshara/letterform and its associated phonetic value.

Handwriting is a fine motor skill, and it requires muscular development for adequate finger movements. As Montessori rightly mentioned, handwriting is the first touch to the letterforms, hence it also uses the tactile sense. A learner first sees the letter, and tries to copy it by a hand-held tool by which he remembers the movements required to execute the letter graphically. At the letter recognition stage, the phonetic association of this form is already established in the memory of the learner which is recalled upon handwriting. Therefore, a phonetic signal is enough to further complete the entire association activity by transferring the letterform on the surface without referring to it into reality.

With repeated audio input of phonetic value associated with the visual form that is seen by eyes, one learns the visual recognition of letterform. Executing the same through speech validates the acquisition of visual recognition.

1.1 Significance of handwriting today

In India, the exams conducted in schools have made handwriting a mandatory medium for solving and answering papers. Hence, acquiring readable handwriting skills is an essential part of formal education in Indian schools. Handwriting helps sustain and preserve the written script culture and thus, for a multi-script country like India, handwriting research on Indic scripts is of paramount importance.

Handwriting is a multi-sensory skill that is responsible for many unknown factors of our brain development. Cognitive neuroscience recognizes the importance of handwriting for brain development.

“There is abundant evidence that there is neural functional specialization for processing individual letters (Flowers et al., 2004; James & Gauthier, 2006; James et al., 2005; Polk & Farah, 1998; Polk et al., 2002- as referred by (James & Atwood, 2009) but, until now, there has not been any work investigating how this specialization may develop. We now present evidence that our experience in writing letters may contribute to the development of functional specialization for letters”. (James & Atwood, 2009)

Therefore our research enquiry is under the primary assumption that, we still need handwriting and that we need to investigate its learning aspect for a new learner. However, we also wish to draw attention to another assumption that technology works as a tool to make human life easier, but without negating the fundamentally important activity like handwriting, that makes human a profound being.

1.2 Identifying the research gap

Research in handwriting began in the early 19th century. On studying a body of continuous research of two decades (1970s to 1980s) conducted in America (Dobbie and Askov, 1995), we discovered that many issues relating to handwriting, are multi-sensory and inter-disciplinary. This further guided us to categorize these researches as per four aspects:

1. Material and Posture
2. Education (teaching and learning handwriting)
3. Language
4. Script (graphic/morphology of letterforms)

The issues related to the first three, have been thoroughly researched before. However, the graphic and morphology of a script has not been investigated sufficiently. As compared to research on Roman/Latin scripts, there is no exclusive

research found on Indic scripts handwriting. One of the reasons may be morphological diversity of Indic scripts.

In handwriting acquisition the input is generally a practicing model letter, and its stroke order to draw it on a surface. This is first demonstrated by the teacher and/or further practiced by using the copy book. These copy books are also known as primers which contains prompts of model letters for handwriting practice. Therefore, before the hand that learns to draw a directed shape of letter, a learner has to practice the basic strokes of a specific script. This stage is also known as handwriting readiness. It involves hand and finger movement in a certain fashion. To dictate the specific hand/finger movement by a handheld tool, practice of copying by seeing is necessary.

In the 19th century, before any formal research on handwriting was published by academicians, practicing schools of calligraphy such as Spencer and Palmer were established. During this era, John Jackson's book, 'The Theory and Practice of Handwriting' mentions Mulhauser's method which decomposes letters into their fundamental strokes. Through this, Jackson points out that practice of basic strokes was essential for handwriting acquisition. However, when formal handwriting research was started, it neither focused on nor neglects Jackson's point.

While searching the available primers for teaching Devanagari handwriting, it was found that basic strokes practice was missing in them. Only one book from 1st standard contained eight basic strokes. Majority of the other existing Devanagari handwriting primers only consisted prompts of complete letterforms and showed no signs of basic stroke practice. Many of them showed usage of divergent shapes of letters as model letterforms for copying. This shows non-standardized approach of these primers towards the morphological and graphic characters of Devanagari script. To see and draw the visible shape of the letter is unavoidably important for handwriting acquisition. Hence it invites specialised graphical or morphological research enquiry.

However, research on teaching and learning handwriting from the point of view of graphic design is yet to be done. It is an area neglected by Indian scientists in the educational domain who work on language acquisition. One possible reason for this

could be, that it is considered to be a part of the motor skill domain. Or a misassumption that it is secondary as compared to language acquisition. Some also think it is a dying skill.

Hence, the research gap can be identified as whether the basic strokes of a script are really essential for handwriting acquisition? To find the answer to this, the basic strokes need to be extracted and validated for their efficiency. Also, due to unavailability of any established method of extracting such basic strokes, the method itself needs to be indigenously designed.

1.3 Scope of study

World literacy count and latest neurological research however tell us a different story. Firstly, according to a recent count, one out of three children is born in bi-lingual environments today and it is increasing. Secondly, learning two scripts simultaneously at an early age is an additional cognitive load on a child. It is currently a challenging issue for multi-lingual/multi-script and highly populated countries. India is one of the best examples of such prevailing situation and hence is a ground for understanding issues concerning handwriting through research into handwriting acquisition.

1.4 Research questions

Handwritten letterform is a composition of strokes. The handwriting learning takes place through these stroke orders. Most of the Indian primers show the order and sequence of these strokes that ultimately complete the letterform. However, independent practice of these strokes before learning complete letter is not mentioned in any of the primers in context to Devanagari. Moreover, the number and sequence of the strokes required for a letter practice as shown in the existing primers differ and contradict from one another for the same letter. Therefore, the first doubt arises, are these primers scientifically designed? Such observation raises further doubt that is basic stroke practice necessary for acquisition of handwriting? In order to gain answers for these questions, one has to test and validate the effect of basic strokes of that script. Hence, the need of extraction of basic strokes was found as a priority.

Therefore, in this thesis we focus our inquiry into the following questions-

- What are the basic strokes for learning Devanagari handwriting?
- Is there a scientific method by which we can extract basic strokes for learning handwriting of a script?
- Does prior practice of script specific basic strokes, help in correct handwriting acquisition? Especially for a second script learner.
- On whom should the extracted Devanagari basic strokes be tested on and what methodology should be employed to validate them?

Chapter 2 Background Study

Across the world, handwriting skill is acquired through regular and systematic practice. Basic stroke practice of each script is inevitable, although it has been given less importance. Every script differs graphically from each other; therefore the basic strokes for every script will differ too. What are the basic strokes for Devanagari script? This primary question is about the process of handwriting acquisition.

There are many factors involved in handwriting acquisition; we claim that the less researched factor is the morphological aspect of the letters. In this chapter we focus on the enquiry through published research literature, about how morphological aspect is studied so far in context to handwriting acquisition.

The stage of handwriting acquisition follows the stage of visually recognizing the letterform. Therefore first, one needs to understand the process of visual recognition of letterforms and then, the association of the visual with its phonetic value.

2.1 Spoken and Written language

The means through which ideas and emotions are expressed is termed as language. Language is divided into spoken and written components. The role of spoken and written language is inevitable. Spoken language is a vital part of communication but gestural and postural signs are integrated to make communication complete.

“Language, as rule-governed behaviour, is described by at least five parameters—phonologic, morphologic, syntactic, semantic, and pragmatic.” (Connell & al., 1982)

Language is a system of signs or symbols unanimously accepted by the society. Over the years, spoken language got more and more refined making communication more perceptible. Thus language is practice-based, means a progressive learning and realisation.

According to the science of language, spoken language is about seventy thousand years old. In the first thirty thousand years, only words were in use. Eventually

sentences using tenses were developed (Devy, 2014). Further, script came into use about six thousand years ago. Hence script is considered as a revolutionary step in the evolution of human civilisation¹.

As Aristotle rightly mentioned, “Spoken words are symbols of mental experience and written words are symbols of spoken words”.² A script is designed by and for human beings. When we write, we use a particular script system. Therefore, writing is yet another means of communication like spoken language.

Script is one of the important approaches which represent culture visually. David Derringer rightly points out, “Script is the vehicle of civilisation” (Derringer, 1947). Peter T. Daniels elaborates further when he says-

"HUMANKIND IS DEFINED BY LANGUAGE; but civilization is defined by writing. Writing made historical records possible. And writing was the basis for the urban societies of the old world. All humans speak; only humans in civilization write. So speech is primary and writing is secondary." (Daniels & Bright, 1996)

2.2 Script Systems

Script is a system of visual marks, primarily designed for communication and documentation of human thoughts or ideas. Process of handwriting is gradual and longitudinal till it attains automaticity. This process is initiated in early childhood, may be that is the reason it is generally taken for granted by grown adults.

The way a script works is usually not thought upon. There are various script systems and each of them works differently, but their function is to execute and document the spoken language.

“Graphic signs on pottery or on cave walls were symbolic, but not yet tied to language. The line between graphic communication, as perhaps represented by such symbols, and what we understood to be the earliest writing systems such as cuneiforms, depend on the point at

¹ Ellis Minns mention in his foreword for David Derringer’s book ‘The Alphabet’ (Derringer, 1947)

² «Logic», prologue to *De interpretatione*. (Panosa, 2004)

which the symbol becomes standardised and fixed in relation to a specific word or phrase. There were various systems that were able to record bits and pieces of language without being able to record all of it.” (Sassoon, 1995)

There are some languages that do not have their own script. Therefore they use a common script. For example, the Devanagari script is used for writing languages such as Hindi, Marathi, Konkani, Nepali and Sanskrit.

According to Derringer’s general classification of script system, two primary writing systems exist today. Derringer termed them as alphabetic and non-alphabetic writing systems (Derringer, 1947). For example one type of script represents phoneme/s and is termed as alphabetic and the other represents the entire word/idea that is non-alphabetic script system. In later times, Derringer’s classification was modified and specified by Daniels and Bright.

Daniels and Bright classified script systems using more specific terminology. (*Ref. table 2.1*)

Table 2.1: Writing systems classification by Daniels (Daniels & Bright, 1996)

Type	Each symbol represents	Example
Logographic	Morpheme	Chinese characters
Syllabic	syllable or mora	Japanese kana
Alphabetic	phoneme (consonant or vowel)	Latin alphabet
Abugida	phoneme (consonant +vowel)	Indian Devanāgarī
Abjad	phoneme (consonant)	Arabic alphabet
Featural	phonetic feature	Korean hangul

2.3 Letter Recognition

Script has two functionalities – reading and writing (Kelkar A, 1983). These two functionalities differ from each other. Let’s understand how letter acquisition takes place in a sequential format.

Reading is processed in stages, seeing and memorising the phonetic value of the letter form, and then recollecting to verbalise is termed as letter recognition. (Ref. Figures 2.1, 2.2 & 2.3)

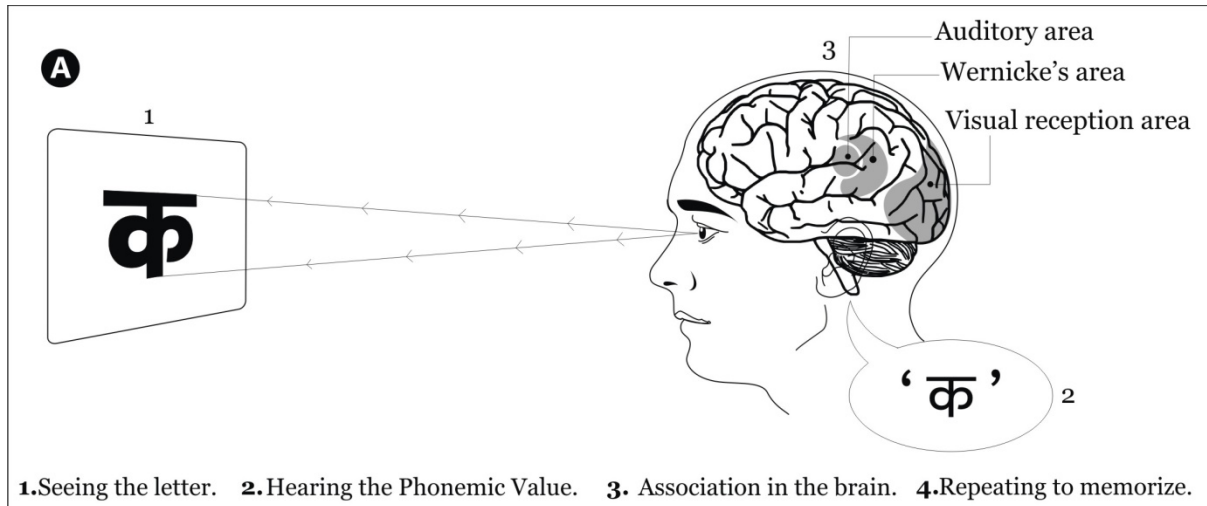


Figure 2.1: Process of letterform recognition Stage One.

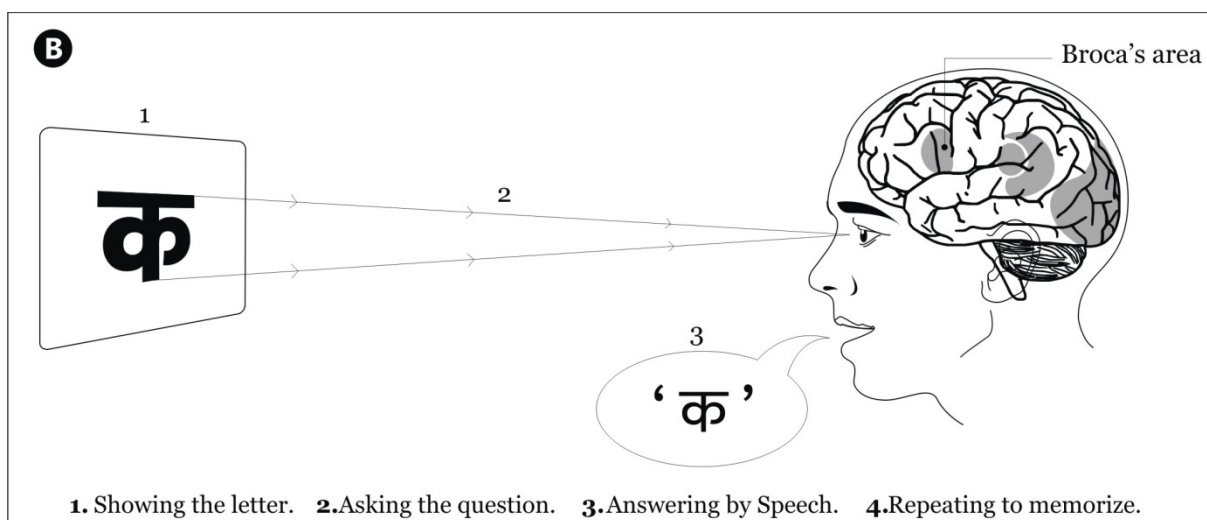


Figure 2.2: Process of letterform recognition Stage Two.

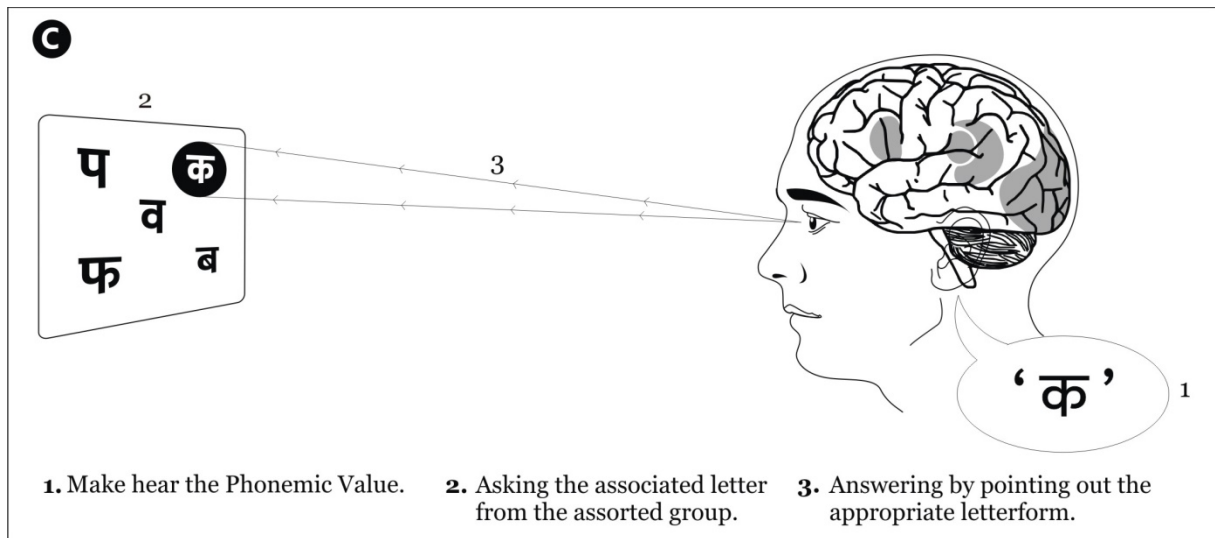


Figure 2.3: Process of letterform recognition Stage Three

Letter recognition can begin at a very early age as basic required physiological abilities are developed by then. For example, learned parents can aid their children with the process of letter recognition even at the early age of six months.

2.4 Handwriting acquisition

The stage of writing occurs much after letter recognition. Since handwriting is one of the fine motor skills, it requires muscular development for adequate finger movements.

Handwriting is the first touch to the letterform; hence, it also uses the tactile sense (e.g. Haptics³). A learner first sees the letter, and tries to copy it by a hand held tool by which he remembers the movement required to execute the letter graphically (*Ref. Figure 2.4*). At the recognition stage, the phonemic association of this form is already established in the memory of the learner which is recalled upon handwriting. Therefore, further a phonemic sign is enough to complete the entire association activity by transferring the letterform on surface without referring to it into reality. (*Ref. Figure 2.5 & 2.6*)

³ Haptic is defined as a combination of tactile perception association with active movements.

(i.e. voluntary movements generated by central motor commands which, in turn, induce proprioceptive feedback). Haptic perception is involved in exploratory hand movements and object manipulation. (Manjen & Velay, 2010)

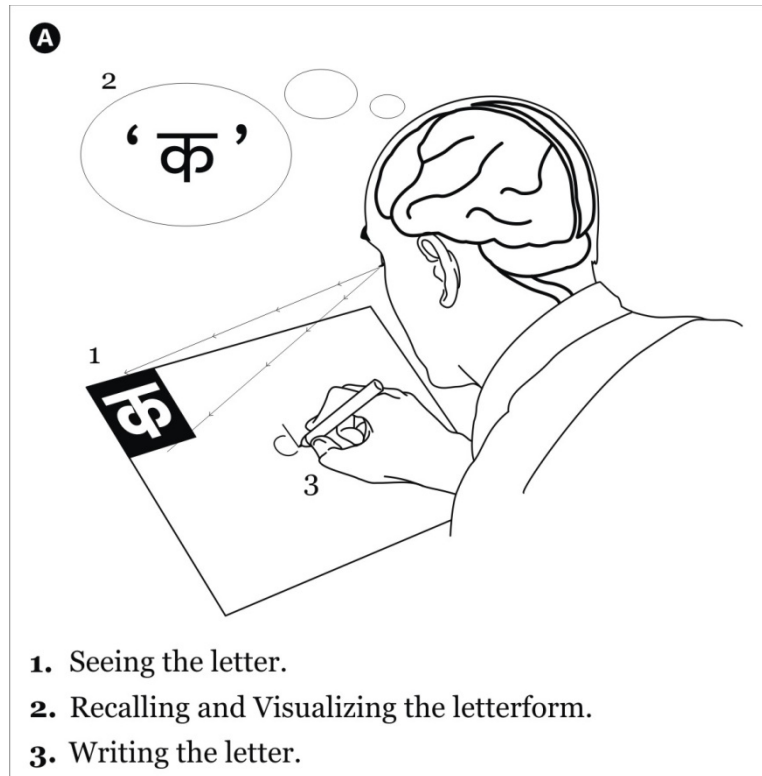


Figure 2.4: Process of writing acquisition Stage One.

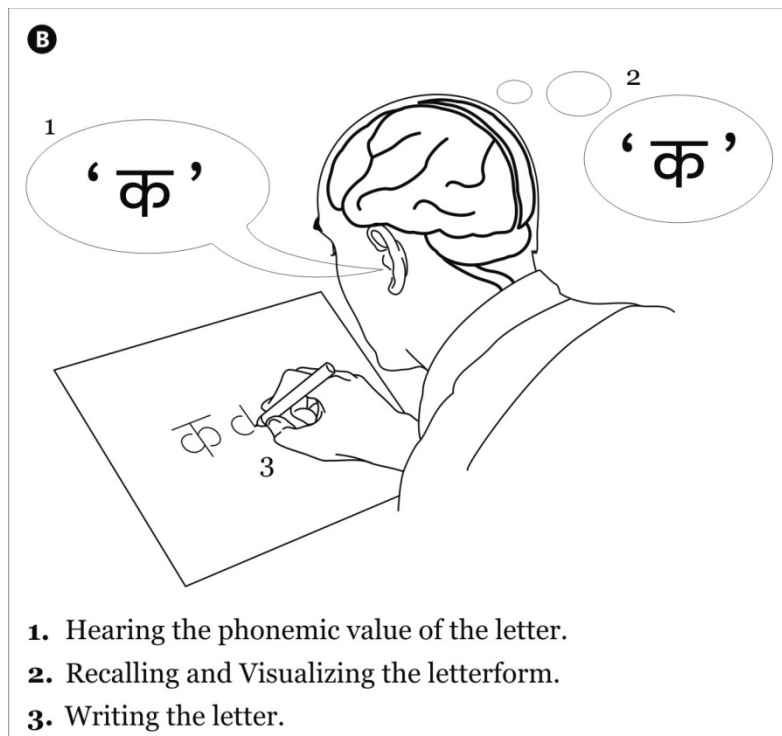


Figure 2.5: Process of writing acquisition Stage Two.

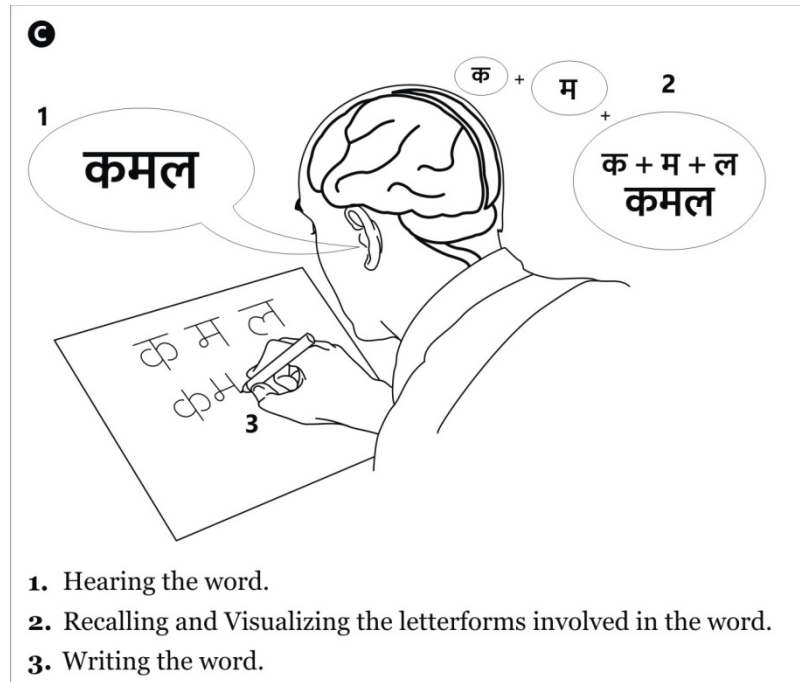


Figure 2.6: Process of writing acquisition Stage Three.

2.5 Inter-Disciplinary Aspect of Handwriting

Handwriting acquisition can be divided into four developmental stages-

Doodling stage: The ability to hold object by hand, progressively develop during the age of 2 to 4 yrs. In this stage scribbling with any drawing tool progressively becomes particular as fine motor activity of fingers developed. This stage is termed as Doodling stage.

Letter Acquisition: In India, when a child is generally 5 years old, he is thought to write by hand. This letter acquisition activity takes place into three stages

- Basic stroke practice
- Complete letterform practice
- Word formation

These three stages focuses more on the morphological aspect of the letterforms.

The enquiry into the process of learning and teaching to write by hand can be theoretically divided into four different aspects. These aspects are inter-related to the above mentioned developing stages. (Ref. Figure 2.7)

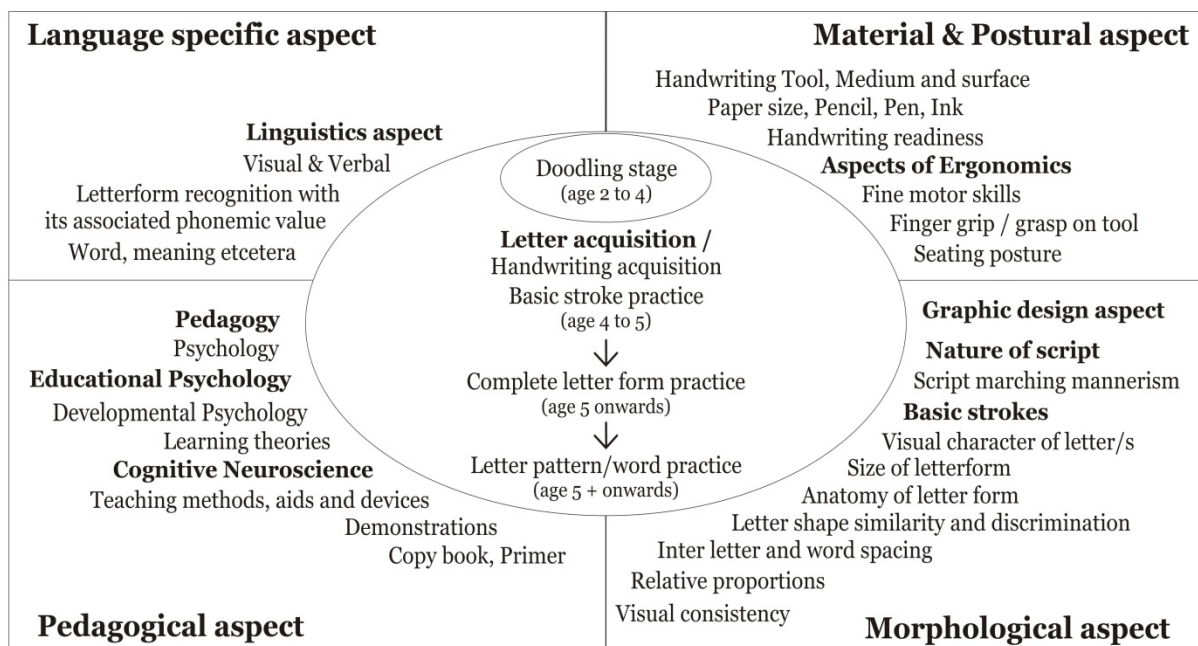


Figure 2.7: Map showing four areas of handwriting research.

2.5.1 Language specific aspect

Language specific aspect of the respective script deals with the idea, meaning and the phonemic association with the symbol.

For instance, in alphabetic writing system, the graphic symbol has more than one phonetic value, while in alpha syllabary writing system, a graphic symbol has a unique phonetic value. Example below (*Figure 2.8*) shows how the word TREE is represented in two different script systems.

T R E E
Alphabetic writing system

ट्री

Alpha Syllabary writing system (ट + र् + ई = ट्री)

Figure 2.8: Word 'TREE' in two different script systems

2.5.2 Material and postural aspect

Various material and postural aspects affect the act of handwriting. Postural aspect ranges from finger-grip on writing tool to sitting posture. In case of material aspect, it is observed that lead pencil as a tool and A4 size of the paper as surface is widely accepted all over the world for teaching and learning handwriting formally (Sassoon, 1995 & Clayton, 2012)

Researchers have rigorously worked on the material (Halpin & Halpin, 1976) (Yakimishyn & Magill-Evans, 2002) and methodological (Freeman, 1912) aspects of teaching to write by hand. Research about postural aspect has identified 6 different types of pencil holds or finger-grips (*Figures 2.9*) and grasps and sitting posture of 2 types: western and eastern. (*Figure 2.10*)

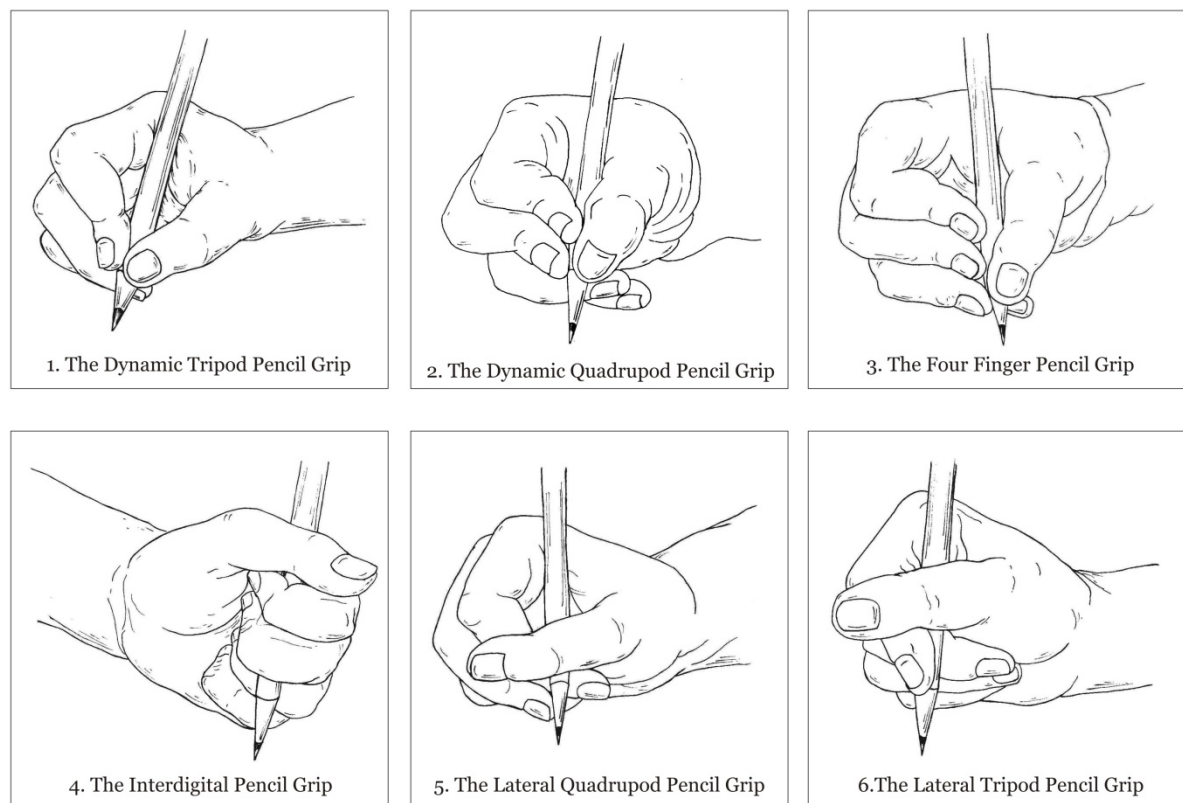


Figure 2.9: The different types of pencil holds or finger grips
(Koziatek & Powell, 2003)

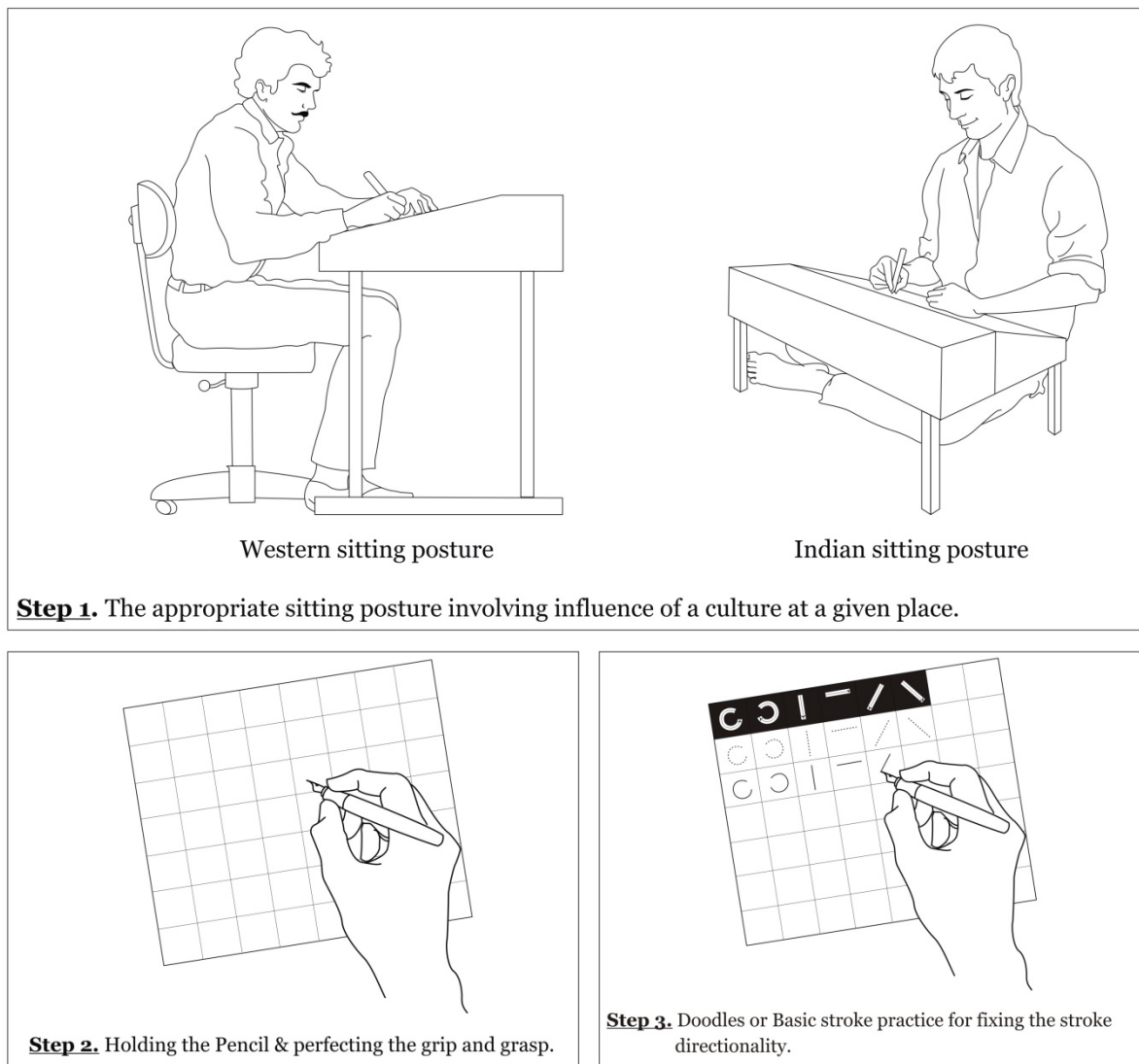


Figure 2.10: Stages of handwriting acquisition

2.5.3 Pedagogical aspect

The educational aspect of teaching and learning can also be termed as pedagogical aspect of handwriting.

For e.g. this includes demonstration one-to-one or in a classroom, drawing the letters on a wall, handwriting practice primers, and use of interactive tools.

2.5.4 Morphological aspect

The shapes of the letters/symbols of each script graphically differ from each other. Every script has its own rules that concerns direction, movements, height differential and spacing. (Ref. Figure 2.11)

Sassoon's table explains ductus of different scripts of the world as follows:

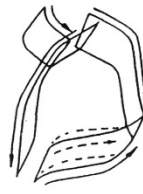
SEQUENCE AND DIRECTION OF STROKES			
			From <i>Learn Hindi in 30 Days</i> , Srinivasachari (1979)
			From <i>The Hebrew Letter</i> , David (1990) reprinted by permission of the publisher, Jason Aronson Inc., Northvale, NJ.
			From an Arabic copybook
			From two different unnamed Chinese copy sheets.

Figure 2.11: Table of Sequence and Direction of Strokes

For instance, the set of rules that govern Latin alphabets are:

1. The direction of writing is from left to right.
2. There are conventional points of entry and directions of the movements or ductus of the letters.
3. Letters are of different heights and these heights are constant in their relation to each other.

4. There are two sets of letters: capital and small.
5. Letter and words are spaced adequately. (Sassoon, 1995)

2.5.5 Morphological aspect of Indic scripts

Currently in India, there exist 22 official spoken languages that are written using 13 different scripts namely Bangla, Devanagari, Gujarati, Gurumukhi, Kannada, Malayalam, Meiti Mayek, Oriya, Ol chiki, Perso-arabic, Roman, Tamil, Telugu.

The Roman script (used for English language) is classified as alphabetic script while most of the Indian scripts are classified as alpha-syllabary group of scripts.

On overviewing the Indic script culture, one can graphically classify them mainly into three categories on the basis of their outer look (Joshi R. K., 1984). Morphologically Indian scripts such as Devanagari, Gurmukhi and Gujrathi are square in shape, while the other scripts such as Bangla, Perso-Arabic are triangular whereas south Indian scripts like Kannada, Tamil, Telgu, Malayalam also including Oriya are circular in shape. Also the marching mannerism (writing mannerism) differs. Most of the Indic script marches from left to right while Perso-Arabic broadly marches from right to left. (*Ref. Figure 2.12*)

Although these scripts are only classified into three categories (Joshi R. K., 1984) when we go into detailed morphological aspect, we find that each of them differs on the grounds of the rules that govern every script.

When only one script is focused upon, it seems that there must be an appropriate way to write the particular script.

“People who only know their own writing system might assume that there is a right way and a wrong way to write, or even one way that works best for the human body. But this is patently not so. Take any one of these rules in turn and compare it within different writing systems, and the variation becomes obvious.” (Sassoon, 1995)

However, the language and morphological aspect of a specific script always remains unique. Thus, the morphological aspect of every script has to be individually analysed. With the morphological variety of scripts, researching into their common morphological aspects is a challenge. Thus, an attempt has been made to understand this challenge more clearly. For this, Devanagari script has been taken as a case study.

2.6 Handwriting Research

Since ancient times, across the globe, handwriting skills were acquired by regular and systematic practice.

There are ancient evidences of writing on surfaces like stones, clay tablets, bones, shells and casted metals. But these writings were definitely more significant than everyday writing. Since handwriting existed even then, it can be inferred that there must be a method of learning to write by hand. But most of the available ancient resources are with regards to calligraphy. In calligraphy, the primary concern is towards beautiful handwriting and readability for the reader. Whereas, the primary concern of handwriting is to write down one's own thoughts for personal purposes. As the primary objective of calligraphy and handwriting differ, the process and the

techniques also differ. Therefore, those resources cannot be taken into much consideration.

One source of research is material based, and another significant source is literature. For instance, way back from 300 AD, Ancient Indian texts mention that handwriting was taught and learned formally. In ‘Lalitavistara’ (translated in Chinese in 308 A.D.) while describing the childhood of the Buddha, it is mentioned that along with other children, Buddha was sent to ‘Lipishala’ (the school for learning script/handwriting). It further refers to a sandal wood board (dust slate) and wooden stick (covered with gold), which was used as a writing tool by Buddha. It also mentions the game called as “Akharika” (Murthy, 1996) which is a rare evidence hinting about the process of practising letterforms. Children played this game by prompting a letterform on the bare back of other child, allowing that child to guess the letterform. Later, the similar idea of tactile prompting method for learning letterforms became popular (Askov & Greff, 1975). This concept came across to us through the terms like perceptual prompt as seen in recent scientific literature (Bara & Gentaz, 2011).

There are certain limitations in obtaining earlier evidences of handwritings. One such limitation is regarding the tools and surfaces used.

Before paper came into use for writing, various surfaces were tried out by various cultures. For example, in India, birch bark, palm leaves etc. were used for writing. While in the west, vellum was used. These surfaces were used to write religious prestigious literature. Since those literary works were of great significance in classic literature, it was found that they were written using calligraphic techniques. Manuscriptologists, Shiv Ganesh Murthy says that the rough drafting of such literature was done on surfaces like lotus leaves, or similar bigger sized leaves of other trees. But all these materials were short lived; hence, evidences of everyday handwriting couldn't be preserved.

Hence the surviving literature only gives hints about tools and material that were used for learning handwriting. Also they are insufficient as they do not mention about the method of learning to handwrite in detail.

R. S. Shiva Ganesh Murthy says-

“Though the clear evidence for writing in ancient India is available as early as 5th century B.C., the manuscripts now available are not generally older than about 600 years (only in few cases, it may be 1000 years or more) because of the fragile nature of the material used for writing. Though many manuscripts of earlier period are not to be had, the history of writing can easily be traced, thanks to numerous inscriptions and epigraphs.” (Murthy, 1996)

While probing into history of learning to write by hand, only through text, one has to accept certain limitations. For example, the resources for earlier used surfaces for documenting are hardly available. And the surviving documents might not necessarily inform us about the process of learning to handwrite. The oldest paper manuscript that is available to us is merely 600 to maximum 1000 years old due to its fragile nature. X Simply by closely looking at any calligraphic manuscript, at the most, one can decode the ductus* of letters but not exactly how those people have practiced and mastered the technique.

By the end of the 18th century, scientific evidences regarding the process of teaching and learning handwriting were found. Approach of scientific research in to ‘act of handwriting’ was found in mid-18th century in America. Dougherty (1917) divides American history of teaching handwriting in five periods, based on the dominant influence or interest at the time. These are as follows:

Colonial Period, 1600-1800

Transition Period, 1800-1850

Period of Independent Elaboration of American systems, 1850-1890

Vertical-Writing Movement, 1890-1900

Combination of Commercial and Scientific Influences, 1900-1916

(Dougherty, 1917)

It is clearly mentioned in American literature that the calligrapher’s method was initially popular. Calligrapher’s method of teaching handwriting was “model based”. While studying this specific process, students used to copy the given model letter very strictly. This method not only insisted upon making the letters beautiful, but also

readable. It was highly influenced by calligraphers such as Spencer (Ref. Figure 2.13) and Palmer (Ref. Figure 2.14).

“When A. N. Palmer and his followers muscled their way into the twentieth century, they thought they had the ornate script of the Victorian age for good and spoken the last word on penmanship. King Spencer was dead; long live King Palmer. There was, however, a second group of penmanship pedagogues who disdained the Palmer method and its look-alike competitors as no better than their predecessors and as untouched by the light of modern knowledge.” (Thornton, 1957)

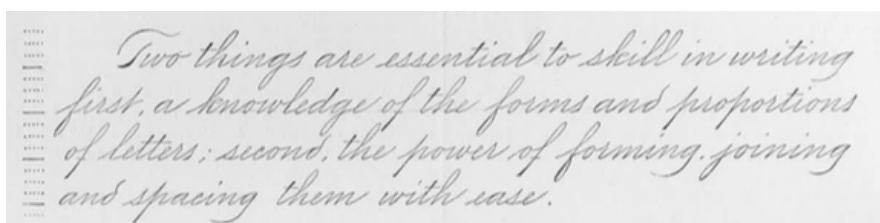


Figure 2.13: Sample of Spenserian Penmanship

(Tucker, 2015)

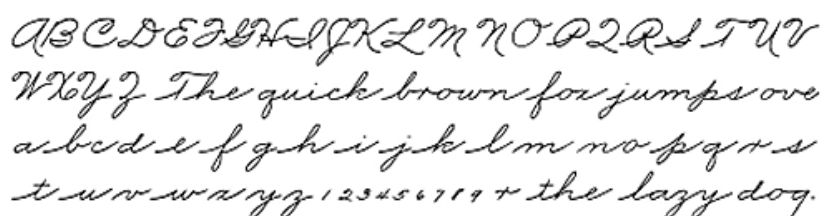


Figure 2.14: Classic Palmer script ⁴

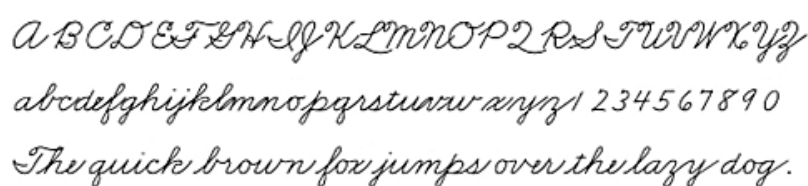


Figure 2.15: Traditional Zaner-Bloser script

⁴ Figure 2.13/2.14/2.15/2.16 are as cited on - <http://www.ancestryinsider.org/2008/07/indexing-tips-1900-american-handwriting.html>, (Illustration courtesy Educational Fontware, Inc.)

ABCDEFGHIJKLMNOPQRSTUVWXYZ
 abcdefghijklmnopqrstuvwxyz 1234567890
 The quick brown fox jumps over the lazy dog.

Figure 2.16: D'Nealian Script

Cursive

ABCDEFGHI
 JKLMNOPQR
 STUVWXYZ
 abcdefghijklmn
 opqrstuvwxyz
 0123456789

Italic Cursive

ABCDEFGHI
 JKLMNOPQR
 STUVWXYZ
 abcdefghijklmn
 opqrstuvwxyz
 0123456789

Figure 2.17 A

Figure 2.17 B

Manuscript

ABCDEFGHI
 JKLMNOPQR
 STUVWXYZ
 abcdefghijklmn
 opqrstuvwxyz
 0123456789

Modern Manuscript

ABCDEFGHI
 JKLMNOPQR
 STUVWXYZ
 abcdefghijklmn
 opqrstuvwxyz
 0123456789

Figure 2.17 C

Figure 2.17 D

Figure 2.17 : Currently used handwriting models

When the calligraphers' method of making a letterform from the schools of Spencer and Palmer became a part of the formal education, it was taken as a scientific research issue by the academicians. Eventually, the spread of learning to write increased through formal education and it was realized that the readability of the letter is the primary aim of handwriting rather than it being just beautiful. (*Ref. Figures 2.13, 2.14, 2.15, 2.16 & 2.17*)

“Cloyd N McAllister and Charles H Judd of Yel and Frank Freeman of the University of Chicago shifted the emphasis from correct form to correct movement.” (Thornton, 1957)

These were the early psychologists to probe into handwriting research. They were amongst the first few scientists during that era, to scientifically present the issues which focused on the process of handwriting.

Freeman's study was a benchmark of American handwriting research. Some of his best known researches were ‘An experimental Study of Handwriting’ (1914), ‘The Handwriting Movement’ (1918). He was the first to investigate primers, thus probing into the morphological aspect of handwriting.

Although these scientists have considered most of the fundamental aspects of handwriting in their research, they only focused on Roman/Latin script. However, Sassoon (1995) states that there are various script systems in the world and they differ from each other morphologically, thus the rules that govern the handwriting system also differ. This makes it clear that there is need for detailed research of every script system exclusively.

There are two important reports that cover the American research based on handwriting from 1980's. Further, Michaelleen Peck, Eunice N. Askov, Steven H. Fairchild also presented American handwriting research reviews (Peck, Askov & Fairchild, 1980). These areas were earlier classified by Herrick and Okada in 1963 and this research was reviewed by Dobbie & Askov in 1995. (*Ref. Table 2.2*)

Table 2.2: Handwriting research areas identified from 1963 to 1995 (Dobbie & Askov, 1995)

1	The nature of letter forms most efficiently and legibly produced
2	Instructional techniques most conducive to children's learning and perceptual-motor development and correlates of skill development in handwriting.
3	Effects of various body part positions on writing performance.
4	Effects of speed and stress on the handwriting product.
5	Effects of instructional sequences on the development of handwriting skill.
6	The nature of handwriting instruments and writing surfaces that facilitate learning to write.
7	Development of new handwriting scales and evaluative materials and means for helping teachers to make better use of existing scales.
8	Use of mental models in forming letters during handwriting instruction.
9	Handwriting instruction for special-needs populations, such as adult literacy and learning-disabled students, remedial education students, and those with neurological disorders.

In the above table, eight of the mentioned nine areas inform about the process of handwriting and not the product of handwriting. The area stating ‘nature of letterform efficiently and legibly produced’ focuses on the output of the process i.e. morphology of the script. These areas of research are based on the principle that the ‘process’ is the cause of product.

Research into handwriting is still ongoing (Jackson, 1894); Graham and Santangelo 2012) and is a vast and multi-disciplinary area.

For example, research into handwriting skill acquisition ranges from the choice of material for learning handwriting (the appropriate tool and surface) (Freeman, 1923) to the diameter of the tool (Wiles, 1943), size of the writing space (guidelines of x-height) (Halpin and Halpin, 1976), the effects of the type of writing tool and the orientation of the writing surface on the pencil grasp or pencil grip (Yakimishyn and Magill-Evans, 2002), the effect of different styles of pencil grips on legibility and speed for cursive handwriting (Koziatsek and Powell, 2003), and the effect of seating postures. Some researches examine how to practice handwriting; for example, Horn (1962) and Enstrom (1969) investigated handwriting research questions on different levels such as –

- i. Developing and maintaining the speed and satisfactory quality of handwriting,
- ii. How handwriting instructions should be designed that will combine group instructions & individual practice to identify disabilities?
- iii. How to reduce the longitudinal aspect attached to the study of handwriting development?

However, research concerning the shape of letters, largely known as the nature of the letterform (Dobbie & Askov, 1995) is evaluated only by a few script cultures worldwide. All such research into handwriting remains exclusively specific to certain script systems.

The visual nature of the script for handwriting purposes is less investigated in the domain of teaching and learning. While probing into the visual nature of scripts, researchers must take one script as a case study, which is accepted by the handwriting research community. The “visual nature” of the script is less universal and more script specific (Share, 2008) in comparison to other subject areas in handwriting research. Eventually, the script-specific enquiry of its “Visual Nature” grows saturated (Smith, 1987; Share, 2008) and, therefore, less useful for the purposes of generalisation.

Far eastern script systems also have different hands while teaching handwriting to school children. There are approximately five different Chinese character styles. Presently, two are used in Japan. One is Kaisho, which is very similar to print writing; the other is Gyosho, a cursive style of manuscript. Japanese children learn Kaisho as soon as they enter elementary school. In junior high school, students study Gyosho (Oshiki). The said study also includes various hands for handwriting that are taught.

The concerns about nature of letterforms differ from one script system to other as well to one Model hand to another Model hand. Although the script is one, different countries use different handwriting models to teach the same script. Even within Roman/Latin centric countries more than one hand is taught. Further, Graham reviewed handwriting research from 1980 to 1994, in which he shed light on the unresolved issue about which hand to follow: the print or cursive?

On overviewing this research it occurs that the acquisition of correct handwriting is a common issue which mainly depends on the appropriate movement of the hand held

tool. The cause of appropriate movement acquisition is appropriate practice at an early stage (Sassoon, 1995).

The above research is focused mainly on Roman script which is used for English language. Since Sassoon says that every script is governed by different rules, thus it is important to study each script individually. Research done in context of morphological aspect of Roman/Latin script may not prove useful in regards to other scripts of the world due to morphological divergence.

2.6.1 Handwriting research in India

India is known for its oral traditions and there is a very scarce evidence of documents on traditional methods of learning letterforms and handwriting. As compared to the research in Roman/Latin scripts, there is no exclusive research for handwriting mannerism in Devanagari. Researchers like Renu Gupta, enquires about Indic group of scripts. But, her focus is more on the letter recognition aspect of Devanagari script.

However, research in letterform recognition of Indic script and research on reading acquisition has been conducted by few scholars (Renu Gupta, Sonali Nag, Anita Gupta, Karanth, Vaidya, Sinha, Jayaram). These researchers emphasize the need of handwriting research in context of Indic scripts exclusively (Renu Gupta, Sonali Nag, Share, Jayaram). The common aspect of this exclusive need is the complexity of Indian scripts,

“Although much research has been done on the acquisition of alphabetic writing systems, especially English, less is known about the acquisition of other systems. This situation has justifiably raised doubts about the relevance and explanatory power of theorizing that has emerged out of Anglocentric and alphabet-centric research (e.g., Share, 2008)”. (Nag, Treiman & Snowling)

Keerti Jayaram in her paper – ELP Part 1 and 2 (2008) has brought forth interventions to support Hindi learners aiming towards strong phonological and orthographic foundations together with skills of meaning construction and thus deals

with Devanagari script. According to Renu Gupta, her interventions can be identified into four approaches which are –

1. Traditional Varnamala approach – The traditional क, ख, ग, घ method of teaching letterforms.
2. Shape Similarity approach – The letterforms are distributed into visually similar groups and then taught to the learners. Example of letterforms with similar shapes e.g. ग, म, भ, न.
3. Alphabetic approach – The Devanagari letterforms are introduced in comparison to the letters of the Latin and Roman alphabetic system, e.g., a= अ, b=ब, c= क, d= ड.
4. Productive Symbol approach – The letterforms are taught with meaning and relevance to the words which they form, e.g., क, ल, म, न. क + आ = का & का + का = काका.

All these approaches are basically teaching how the Indian (Alpha-syllabary) script system works. Among the above, the Productive symbol approach stands out to be more practical as it helps the learner to actually apply what one has learnt and stay in constant touch with the effect. However, all the four approaches or methods are more focused on the visual recognition of letterform along with its phonetic value that aids towards the formation of words and its reading sequence. Thus, with regards to writing, an exclusive research enquiry is needed as it is an integral activity of letterform acquisition which uses tactile sensory predominantly.

Bhagwat's research is more specific to our enquiry about the morphological aspect of handwriting. However, we found that his study of roman script for handwriting is lopsided as compared to Devanagari script. In his research he tries to prove Roman script structure supports faster handwriting as compared to Devanagari script. However he has missed the point that the roman script is alphabetic and Devanagari is alpha-syllabary and they are used for two completely different languages. (ref. Appendix- I) However, Language aspect and Morphological aspect of script always

remains unique to its respective language. Thus, the graphic/morphological aspect of every script has to be individually analysed.

2.7 Insights from Background study

We began with understanding the importance of spoken and written language and its scientific definition. Understanding the historical development of the script was important as it gives a distinctive position to the script.

Every script system is deeply integrated with the spoken language/languages which gives it a distinct character and individuality (*Ref. Section 2.1 & 2.2*). A script system is preserved by the civilisation through its persistent usage (Danieils & Bright, 1996). Handwriting is one of the means to preserve it. Therefore, as every script system is different from the other, every script needs to be enquired individually for handwriting purposes. Due to this, findings of the research conducted on Latin script system proved less useful in regards to the other scripts. Furthermore, we focused on how the letter and handwriting acquisition process takes place which made us realise that handwriting activity is a multi-sensory activity and hence inter-disciplinary.

The interrelated aspects of handwriting – i. The language specific aspect, ii. Material and postural aspect, iii. Pedagogical and iv. Morphological aspects, made us realise that the first three aspects are quite independent to the script as compared to morphological aspect.

We found the need for a morphological grouping of the letterforms from handwriting point of view and prepared a basic level morphological categorisation of Indian scripts (*Ref. Figure 2.12*). This table/chart validated that the morphological aspect of each script always remains unique and hence should be individually analysed. We then extensively probed into the morphological aspect of Devanagari script.

As the letterforms, tools, and material used over the period of time have changed considerably, the historic evidences found on these is unusable in today's time. However, faint methodological aspects such as Akharika, has some relevance. This validates what Sassoon says in her book, *'The acquisition of second writing system'*.

“Attitudes all over the world are changing, however, and traditional tools are being discarded in favour of modern pens. They are used because of their availability and convenience, and sometimes as a symbol of rebellion against older cultural restrictions”. (Sassoon, 1995)

In spite of three decades of handwriting research in America, the issue is still unresolved about which hand (style) to follow, print or cursive. Print emphasises on the readability of the reader, whereas cursive is more concerned about the fluency of the writer. The available sources on the morphological aspect of handwriting research are Roman/Latin centric which is found to be extraneous for the morphological aspect in context to Devanagari handwriting. Nevertheless, some insights were found worth adapting, for instance, Freeman begins his handwriting research enquiry by conducting a survey of existing handwriting primers. As even today, the handwriting primers and other educational aids are the responsible media for the process of handwriting acquisition, we further enquire about the existing primers and teaching aids for Devanagari script.

2.8 Devanagari

Bright classified Devanagari script as ‘Alpha syllabary’ and Daniels referred to it as ‘Abugida’ (Daniels & Bright, 1996). Further it was categorised as an ‘Akshara’ script (Share & Daniels, 2015).

Over time, like other Indian scripts, Devanagari evolved out of the Brahmi script. Brahmi dates back to 3rd century BC. Devanagari was earlier known as Nagari script. Nagari means that which is used in the Nagara or used in the city (Nagar is original Sanskrit word for city). One of the meanings attributed to the Devanagari script is- the script that is used by Devas (Devas=knowledgeable people, knowledge seekers) in Nagara. Therefore it is known as Deva+Nagara = Devanagari.

Resemblance has been found between the Devanagari script used now and the Devanagari script dated back to 11th Century. The Shravanbelgola inscription shows the Devanagari script with its prominent top line feature (*Ref. Figure 2.18*). Every single letter had top line, even when a word was written; the constituent letterforms

did not share a common top line. But in later times, it was found that the top line continues for each word. This top line prominently differentiates the character of the word visually.

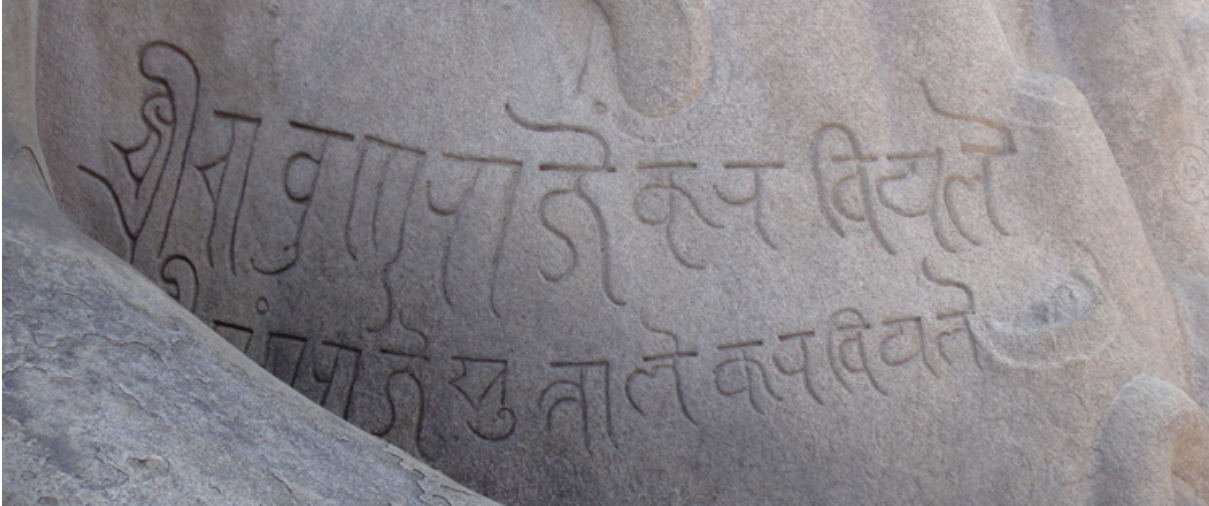


Figure 2.18: Shravanbelgola inscription, 11th Century AD

Devanagari consists of 48 symbols on a basic level, out of which 14 are vowels and 34 are consonants. When consonants come in contact with the vowels, a unique mark is added on a specific side of the letterform such as right, left, top or bottom. These marks are known as Matras.

E. g.

Vowels = V

Consonant = C

C+C = conjunct consonant cluster

C+C+V = conjunct consonant cluster with vowel sign.

This is how the script proceeds further.

Devanagari is written from left to right and has a continuous top line on every word in a sentence. Therefore all Devanagari letterforms have a top horizontal line. Out of 52 letters 29 have right-aligned vertical bar, 14 start with a small vertical bar, 4 letterforms have a middle bar dropping down vertically from the top line at 90 degrees, 3 with drops by circular stroke from the top line. 2 letters are odd. Apart from these geometric visual features, Devanagari also has interestingly compound

clock and anti-clockwise curves with knots with close and open ended loops. (Ref. Figure 2.19)

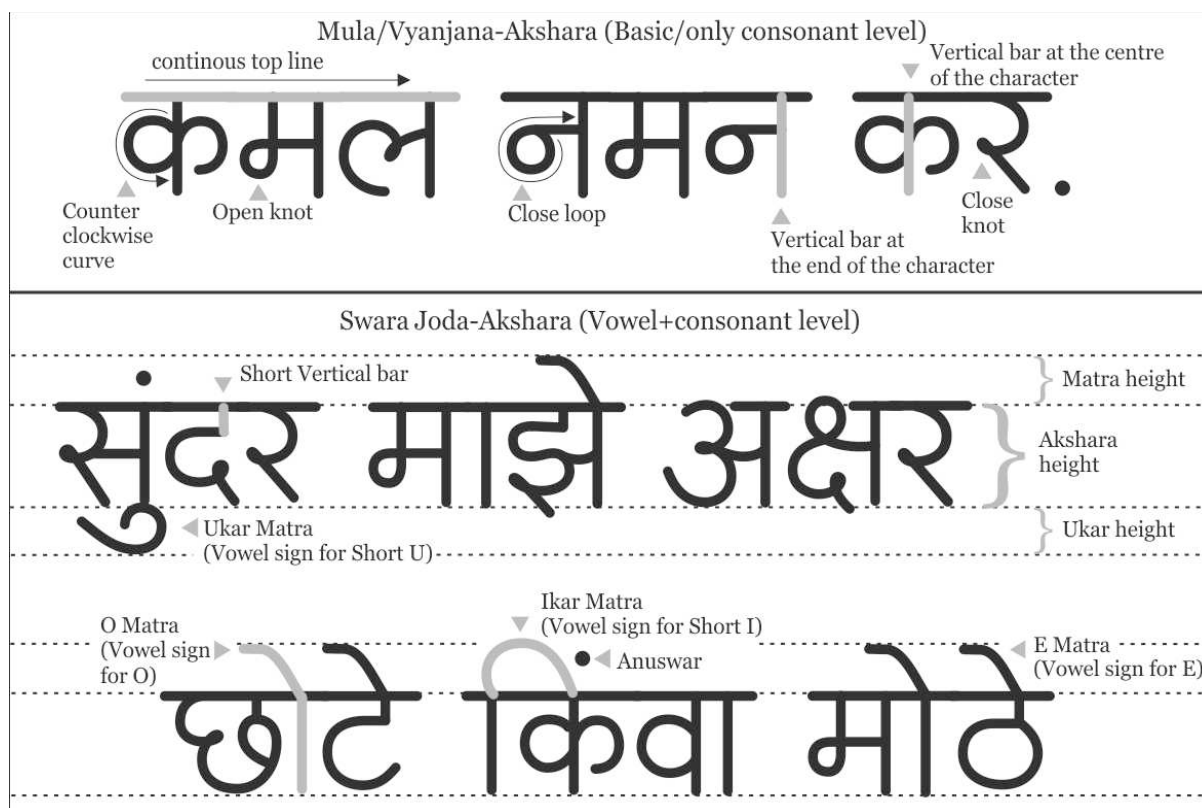


Figure 2.19: Features of Devanagari Script.

2.9 Aids for teaching Devanagari

Many traditional as well as contemporary methods, devices, games and puzzles exist in various cultures. A few traditional and contemporary Indian learning aids are discussed below.

2.9.1 Dhul-paati (Dust Slate)

A popular learning aid for writing, in the pre-printing / early printing era in India, was a dust slate. Dust was spread on a flat wooden flange, and a wooden stick or finger was used as a tool to draw/ practice letters. This fine dust was filtered from a metal mesh. The use of fine dust would result in achieving clear letters on the wooden flange (Murthy, 1996). (Ref. Figure 2.20)



Letter 'Ka' on a 'Dhul-paati'



Letter 'A' on a 'dhul-paati'

Figure 2.20: Dhul-paati

2.9.2 Stone Slate and Chalk

Stone slate and chalk were also available during the period of the dust slate, but these were comparatively expensive. The slate was made out of polished blackish-grey slate stone framed in a wooden case. The white chalk pencil was made out of limestone. This allowed the child to draw white letters on a black background. This is similar to a blackboard and a chalk used by a teacher in the classroom. Due to the playful age of the child, the stone slate would break many times. Hence stone was replaced by black coated metal sheets and eventually by plastic. This learning aid is in use even today.

2.9.3 Taktaa (chart)

A Taktaa is a wall hanging consisting of big sized letterforms along with their associated word and picture, arranged in a typical checker fashion. It is colourful to attract attention of the children. Earlier, these charts were found only in classrooms. Nowadays, due to cost-effective printed reproductions, they are commonly available for personal use as well.

In the 19th century, a unique attempt was made by Narahar Bhawe. He designed a smaller personalised version of the letterform chart on a cloth meant to wrap schoolbooks (Bhave, 1987).

The advantage of the 'dhul-paati' and stone slate was that one could practise letters many times by wiping the surface clean. Hence, the ready visual reference of a letter was not available unlike the Berge Surekha slate.

2.9.4 Berge Surekha Slate

This patented product is solely made to learn a letterform by practice. Written letters are engraved on a plastic sheet (*Ref. Figure 2.21*). A child is expected to move a pointed pencil through the grooves of the letter. However, this product appears as if it is meant to improve the handwriting of the learner and not to grasp the nature of the letter. Another drawback is that since no visible image is created, the child gets bored with the activity soon. Therefore, this method hardly achieves the desirable result. This may be a reason why it is not a popular learning aid even if it is available in a few places today.



Figure 2.21: Berge Surekha Slate

Various researches regarding Devanagari reading acquisition has been carried out by taking different languages as a case study (Jayaram, 2009; Gupta, 2012; Rao & Singh, 2014). However, research into Devanagari handwriting acquisition is neglected. Few researches about the process of handwriting have been carried out but the morphological or the graphical aspect of it has not been studied in detail. The

morphological aspect of handwriting is affected and controlled by primers and handwriting practise manuals.

2.10 Survey of existing Devanagari primers

Observations on the first Marathi printed book/primer used in formal schools:

Palande's entire book is printed using the letterpress printing process (*Ref. Figure 2.22*). The comment on the cover page says if the book needs to be reprinted; only the recommended type face should be used. This shows the author's concern for the shape of the letterforms.

This primer was created specifically for teachers since during that era handwriting primer was not affordable by all. The author specially focuses on teaching conjunct consonants 'Jodakshar'. An exhaustive list of the conjunct consonants cluster, compound letter forms are shown in fairly big size and also their usage with their structural joinery is clearly given.

सरकारी शाळांतील मुलांकरितां

पहिलें पुस्तक.

रा० सा० भास्कर दामोदर पालंदे

द्यानीं केलें होतें तें,

कायम ठरानां छापावयाकरितां

मेहरबान दिरेक्टर आफ् पब्लिक इन्स्ट्रक्शन्

द्याच्या हुक्मावरून

मराठी त्रान्स्लेटर

द्यानें घोषून तयार केलें.

हिंदुस्थान सरकारच्या सन १८६७ च्या २९व्या आक्टा-
प्रमाणें मालकी नोंदली आहे.

भावृत्ति दुसरी.

मुंबई.

गवर्नमेंट सेनल बुक दिपो.

इसवी सन १८७०. शके १७९२.

किंमत (१/॥) दोड भागा.

लहान मुलांकरितां पहिलें

पुस्तक.

मूळाक्षरें.

स्वर.

अ आ इ ई उ ऊ
ऋ ॠ ऌ ॡ ए ऐ
ओ औ अं अः

व्यंजन.

क ख ग घ ङ
च छ ज झ ञ

६

ठ ठ ड ढ ण
त थ द ध न
प फ ब भ म
य र ल व
श ष स ह
ळ क्ष ज्ञ.

अंक.

० १ २ ३ ४ ५ ६ ७ ८ ९

सूचना. शिक्षकांनें प्रथम क्रमानें वर्ण शिकवावे. त्यांची
पक्की माहिती मुलांस झाली म्हणजे क्रम सोडून मधले मधले
वर्ण त्यांस शिकवावे.

१८

जोडाक्षरें.

शिक्षकास सूचना.

जोडाक्षरें शिकवितांना दोन भगर तीन अक्षरें कशीं
जोडलीं जातात हें शिक्षकांनें मुलांस दाखवावे.

कोठें कोठें एकाखालीं एक लिहितात; कोठें कोठें एकापुढें
एक लिहितात; कोठें कोठें पहिल्या अक्षराचा काना सोडतात,
किंवा त्याच्या कोणत्याही भागाचा लेप करतात.

खालीं किंवा पुढें जें अक्षर लिहिलें असतें त्याचा उच्चार
मागून होतो.

मीं जोडाक्षरें लिहिलीं आहेत त्याहून आणखी पुष्कळ
आहेत. तीं द्यावरून समजतील.

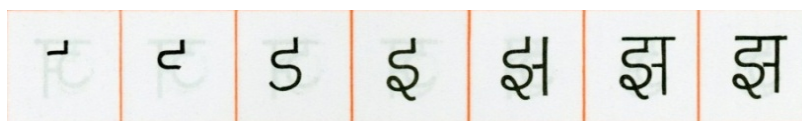
(कक)क्क (कत)क्त (कय)क्य (कर)क्र,क्र
(कव)क्व (खय)ख्य (गन)ग्न (गय)ग्य
(गर)ग्र (गल)ग्ल (घन)घ्न (चच)च्च
(चछ)च्छ (जज)ज्ज (जय)ज्य (जव)ज्व

Figure 2.22: Palande's Devanagari primer

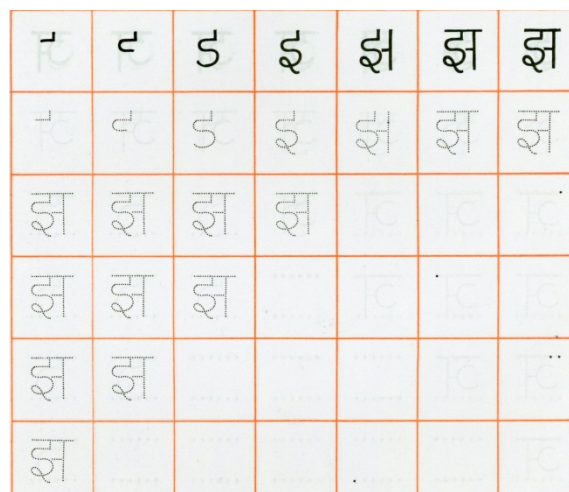
2.10.1 Handwriting practice primers

There are two types of primers found – one for handwriting practice and other for letter recognition, we name them as type ‘W’ and type ‘O’ respectively. A primer contains information about the formation of the letter structure systematically in a segmented fashion. A child is expected to learn to write by rendering the letterform a certain number of times.

A writing practice primer simply gives instructions like “see, trace, and copy” (write). Each letterform is dissected into three to five segments. A child is expected to understand how to write the letter by tracing and practicing. Some of these exercise books at least show a gradual formation of the letterform. Tracing prompts (7) give a clear idea of letter formation in a stroke-by-stroke fashion. The tracing prompts in *Figure 2.23* show that it is assumed that a child understands the entire letterform just by looking at it. Primers are meant for children of age five years and above.



Typical segmented letterform development.



Typical faded tracing prompts.

Figure 2.23: A page from primer-‘Navneet publication’

2.10.2 Layout of primers

Generally, all the books have one letterform per page arranged in phonological order. A model letter with a corresponding word and illustration is shown at the top of every page. Below the model letter, space is provided to practice the letterform. The first line consists of a visual indicating the sequence of strokes, pen lifts, and directions required for the formation of the letter. The number of times a letterform can be practiced varies from 30 to 57. There are also 3-6 words in approximately 18 pt. size and the children are expected to underline the letterform practised on that page from those words. It confirms whether the child is able to identify the letterform that he has practised. However, grouping of the letterforms according to the form or structure is missing.

2.10.3 Model letterforms in primers

The size of the letterform ranges from 48 points to 72 points. Most of them use 72 point size. Interestingly, in the case of Devanagari books, these letterforms are found to be thick and thin (cut pen type) in character. A very basic structure of the '*Balbodhi*' hand is found in these letterforms. A relative proportion of the thick-thin character varies from one book to another. Some books use existing typefaces whereas lettering by hand is used in others. These model letters are inconsistent in their overall structure and look.

The question that arises is- why is a type that is primarily designed for reading (from a reader's point-of-view) used as a 'sample aid' for learning to write?

The modulated strokes of the model letterforms contradict the mono-liner strokes produced by a pencil used by a child.

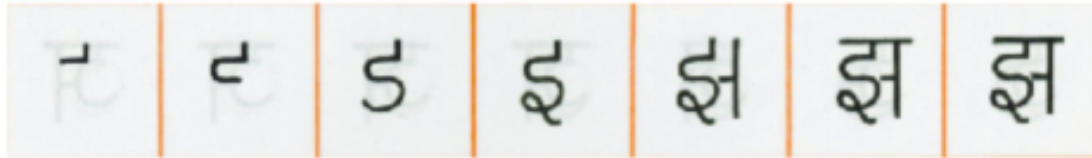
2.10.4 Stroke sequence in primers

- Irrelevant Pen lifts:

For teaching Devanagari script (Marathi/ Hindi) the primers which are used vary in their demonstrations for writing a particular letter form. For example the number of

strokes and the stroke order of a particular letter form are different in various primers. (Ref. Figure 2.24)

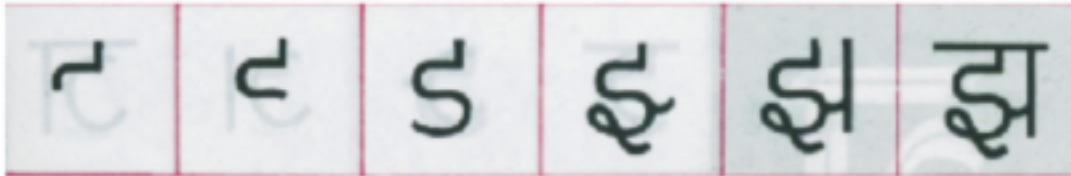
The following are the samples of a particular letterform and its demonstrations from different primers.



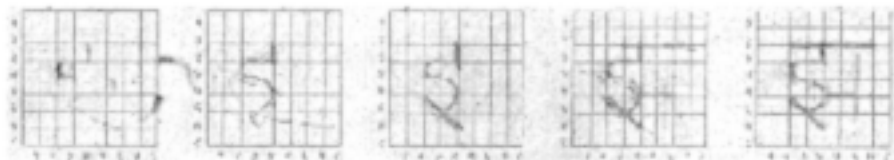
1. Marathi Akshar Olakh



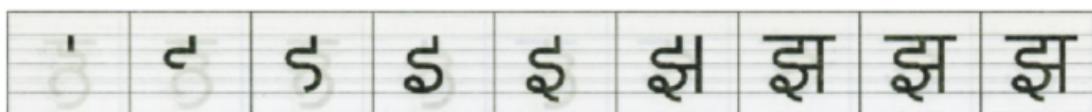
2. Hasat Khelat Akshar Olakh



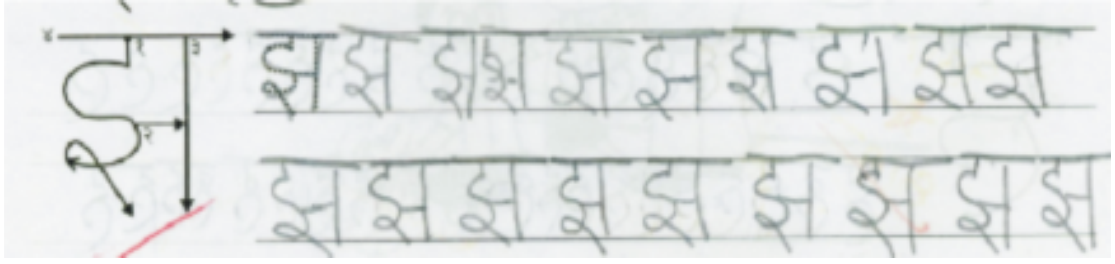
3. Naveen Marathi Akshar Olakh



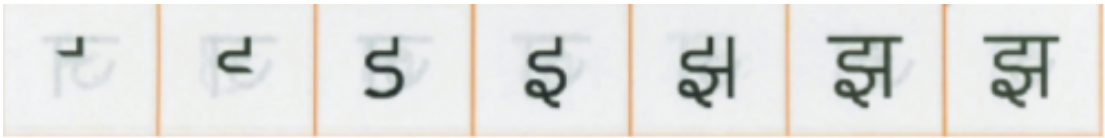
4. Akshari, Ankalipi



5. Marathi Sulekhan 1



6. Maze Pustak



7. Hindi Varnamala 1

Figure 2.24: Sample of particular letterform across different handwriting primers

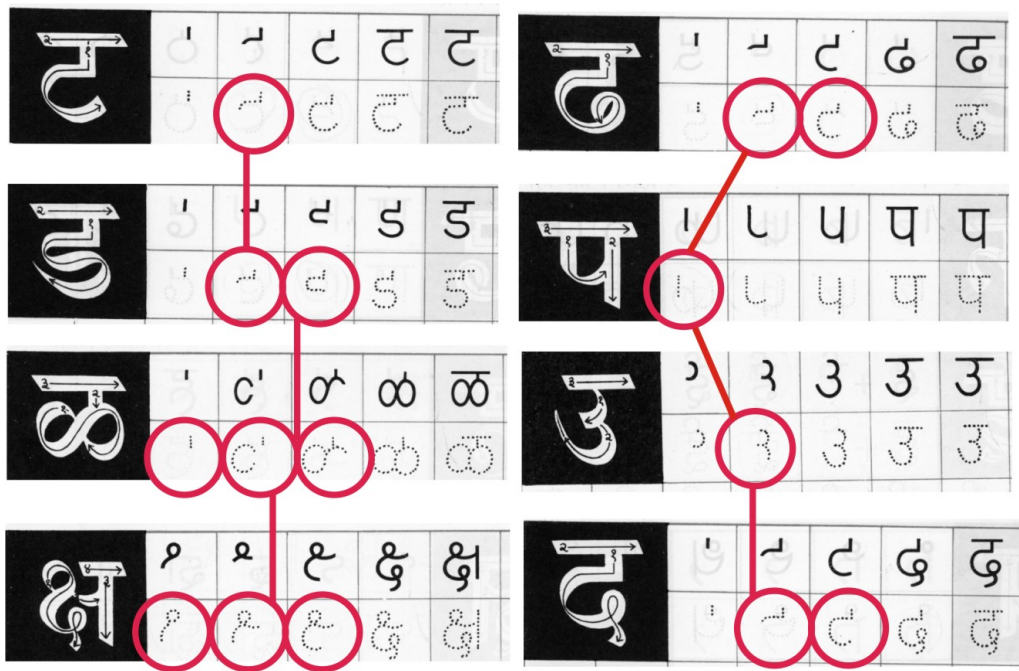


Figure 2.25: Variation in segmentation of letters within a single primer.

This writing practice primer shows a pen lift or the subdivisions in a moving stroke at almost every turn of a stroke. This is not required while using a mono-liner tool to write. After studying the data, it was observed that the breaks in the segment of the stroke and the pen lifts do not match. Their irrelevance can be seen especially in the case of letters 'क्ष' and 'क'. (Ref. Figure 2.25)

- Disproportionate size and manner of showing ‘Anuswara’: (Disproportionate ‘Anuswara’, ‘Visarga’)

With a mono-liner tool like pencil, The Anuswara, Visarga and the dot in ङ is written as a single dot, and not as a hollow circle, as shown in *Figure 2.26*. One can see three variations in the shape of the dot within the page of letter ङ.



Figure 2.26: Disproportionate size and manner of showing ‘Anuswara’.

- ‘Calligraphic’ manner for writing creates confusion.

The way a letterform is drawn may vary according to the tool used. The knot of the ख and र in *Figure 2.27* is drawn according to the ‘calligraphic manner’ while writing with a cut pen. But while writing with a mono linear tool a fly-loop is more convenient.

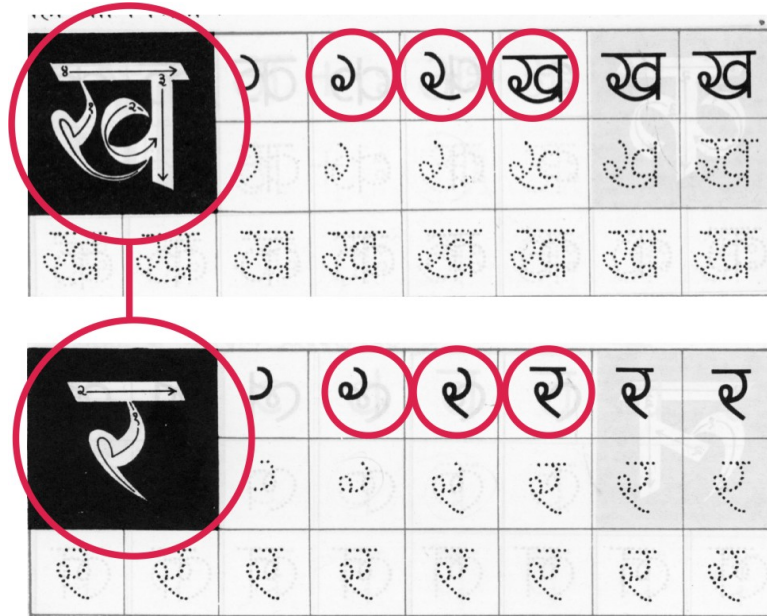


Figure 2.27: Calligraphic model letterform in existing primers.

- Observations about model letterform and written letterform:

In *Figure 2.28*, the Structure of *ल* in the Model Letter varies as compared to the structure of *ल* in the tracing prompts. The structure of the model letter is based on the calligraphic manner, whereas the tracing prompts are based on the handwriting manner. This variation may create confusion.

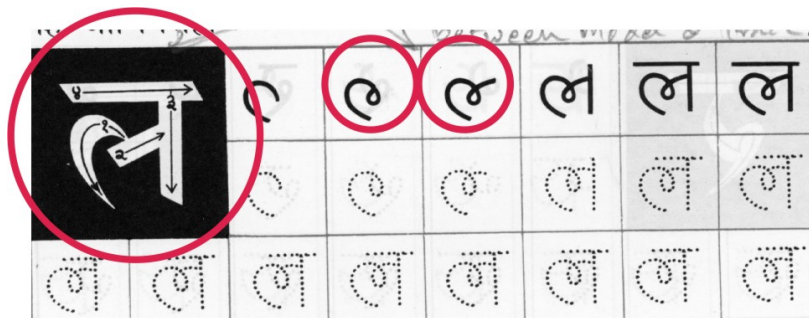


Figure 2.28: Difference between model letterform and tracing prompts.

- Variation in the structure of a letterform across different primer:

Figure 2.29 shows the variations in the structure of *र* in the tracing prompts, across various primers.



Figure 2.29: Variation of model letterform across different primers.

Most of these books, manuals, primers have copied the earlier manuals blindly. There is a range of small and big publishers; therefore, these books are available over a vast price range. However, they have a common intention to deliver the same content or information. It is very interesting that although the same content needs to be delivered for the same purpose, there is a wide range of variation in the presentation of the content. The first exposure to a letterform is a very fundamental issue since it is meant for children with no background information. Curiously, such books fall into the pre-school category. Many variations in shapes of model letter were found in the same book. It seems these new primers and books have offered nothing but finesse due to the new printing technology and competitive pricing. In short, they have just changed the surface look but they are not developed according to the need of the hour. It is expected (ideally) that these books, should be scientifically researched and then designed.

2.10.5 Insights from Devanagari primers

Following are the insights derived from data analysis of Devanagari primers.

- Number of strokes along with stroke sequence to build each letterform varies from one primer to the other. This creates confusion about which primer should be followed.
- As per American research terminology, Devanagari script follows only print hand for handwriting, as no slant or cursive hand is in use today. This was inferred after analysing the Devanagari primers. (*Ref. Figures 2.17–A, B, C, D*)

- The data allows us to confirm that in case of Devanagari handwriting only one hand (print hand) is followed for more than a century (Palande 1875, Navneet Publication 2012). (*Ref. Figure 2.22*)
- As only one hand is followed in teaching and learning Devanagari handwriting, the question raised is why variety of primers are showing multiple mannerism in Devanagari morphology. Therefore, one can logically claim that no standardised stroke order is seen in any of the available Devanagari handwriting primers.
- The fact revealed through data analysis is that existing Devanagari practice primers have ignored the basic stroke practice. To build a logical and sequential order of strokes for Devanagari, the fundamental step is to understand which are those basic strokes and their directionality. Therefore, we further claim that there is a need for the extraction of basic strokes for Devanagari script.
- The basic stroke practice with appropriate direction of the stroke leads to build a habit of suitable hand movement, which further leads to acquire appropriate letter formation. (Sassoon, 1995)

This enquiry raises questions such as –

- Which are the appropriate basic strokes for the Devanagari handwriting practice?
- How to methodically extract and confirm the extracted basic strokes?
- How to validate the extracted basic strokes?

Chapter 3 Manual extraction of Devanagari primitives

In previous chapters it is concluded that no primers include basic stroke practice for Devanagari before complete letterform practice. Furthermore, previous chapters have also brought forth fundamental questions like whether the basic strokes present in the previously mentioned standard 1 school book are sufficient to cover the core graphic nature of Devanagari script.

First we concentrate on theory and the methodology used to conduct the enquiry. As the act of handwriting is a fine motor skill, we focused on those areas of theory that dealt with cognitive processing of a child or learner that result into skill acquisition.

3.1 Theoretical Support

Learning is also a process of acquiring knowledge and skills through experience and practice. Benjamin Bloom in 1948 suggested three different domains of learning, namely - cognitive, psychomotor and affective. These three domains are interrelated to each other. For instance, while learning to write, understanding the relation between the phonetics and graphic values of any given letterform is essential (cognitive domain). Along with this, it is essential to learn the techniques to write with a hand held tool (psychomotor domain). Further, a person acquires fluency in the act of handwriting (affective domain).

As learning handwriting is a longitudinal process, it is affected by many factors during its course.

In 1960 Bruner's text, *The Process of Education* was published. The main premise of Bruner's text was that students are active learners who construct their own knowledge. Bruner in 1960 explained how this was possible through the concept of spiral curriculum. This involved information being structured so that complex ideas can be taught at a simplified level first, and then re-visited at more complex levels later on. Therefore, subjects would be taught at levels of gradually increasing difficulty (hence the spiral analogy). Ideally, teaching his way should lead to children being able to solve problems by themselves.

The purpose of education is not to impart knowledge, but instead, to stimulate a child's thinking and problem solving skills which can then be applied to a range of situations. The role of the teacher should not be to teach by rote learning, but instead to facilitate the learning process. This means that a good teacher will design lessons that help student discover the relationship between bits of information. (Bruner, 1961)

The letterform is a graphical representation of phoneme or idea. Phoneme is the distinct unit of spoken language which can only be heard, while idea, in context to letterform, is a visual symbol. Therefore, letterform is a tangible representation of an intangible subject like phoneme or idea, for instance, Ideographic Kanji, Phonetic Indian script and Alphabetic Roman script. Letterform itself is an abstract idea. Therefore it has no external reference for comparison and thus, a new learner has to always follow a man-made model of letterform.

Our study deals with the act of handwriting with a graphic perspective. The letterform can be defined with a graphic perspective as a complex compound of strokes. On the grounds of Bruner's theory of learning we assume that, if complex ideas are dissected into simplified basic levels, it becomes easy for the learner to approach the problem solving stage by themselves.

In our case study for the acquisition of letterforms, the extraction of basic strokes is fundamental. This fact justifies the inclusion of basic stroke in handwriting primers.

Dissecting complex letters into simplified bits (basic strokes) needs to be enquired practically. Therefore, an experimental approach was chosen.

A qualitative approach was followed to manually extract Devanagari primitives. Part one of this exercise needed students who must have learnt Devanagari as first or second script in school. And as this enquiry concentrates on the graphic property of the letterform, students (age group 19-21) pursuing graphic design were selected.

Part two of this exercise needed experts from the field of typography of age group 23yrs-32yrs, with experience ranging from 2 years to 10 years.

As elaborated in Chapter 2, the nature of the script for handwriting is not investigated adequately in the domain of teaching and learning. While probing

into the visual nature of scripts, a researcher has to take one script as a case study. This is understandably convenient for a researcher and also accepted by the handwriting research community. Another reason is that the ‘visual nature’ of the script is less universal or more script specific (Share, 2008) in comparison with other subject areas in handwriting research. Eventually, the script specific enquiry of its ‘visual nature’ grows saturated (Smith, 1987; Share, 2008) and therefore less useful for the purposes of generalisation. Researching with one script and probing into a more holistic idea, in the world of scripts for handwriting, is a challenge. We probed into a school book, which is one of the key devices used in the process of teaching and learning handwriting formally. In this chapter we propose a systematic process of extracting Devanagari primitives for handwriting.

3.2 Primitive extraction: An exercise

Upon investigating the first grade book prescribed by the syllabus, namely ‘Marathi Pustak Pahile,’ we found that the very first lesson is about the practice of basic strokes, meant for handwriting readiness (*Ref. Figure 3.1, Appendix I-a*).



Figure 3.1: Devanagari basic strokes as seen in a first grade school book

(Refer Appendix I-a)

While comparing these prescribed basic strokes with Devanagari handwriting, a doubt arose concerning their sufficiency for handwriting readiness in Devanagari. Therefore, the following questions were raised:

- a. What is a basic stroke in the context of handwriting?
- b. Which should be the basic strokes for Devanagari script?
- c. Is there a standard method to extract basic strokes of a script?

As there is no standard method to extract the primitives of Devanagari script for handwriting purposes, we designed an exercise. This exercise is divided into two parts.

3.3 Two parts of the exercise

We conducted the entire exercise in two parts. In part one, six random participants received general instructions on how to separate the Devanagari basic strokes manually. On the basis of the insights received from part one; we made a final inventory of basic strokes deconstructed from a set of Devanagari letters for handwriting. In part two, five expert participants received specific instructions, based on the strokes illustrated in the prescribed school book, to perform the same task. Clustering them visually, as well as on the basis of similarity of movement/direction led us to find appropriate and sufficient primitives for Devanagari handwriting.

3.4 Part One of Exercise

3.4.1 Procedure

Students between the ages of 19 and 21 years, who had learnt Devanagari as the first or second script in school were randomly selected as participants.

3.4.2 Instructions

Place the tracing sheet (translucent sheet) accurately on the letter sheet that is provided. (*Ref. Figure 3.2*)

1. Extract primary strokes from the given set of Devanagari letters.
2. Extract the most essential stroke/s by rendering them in ink pen/marker on the given translucent sheet.
3. Make a group of similar strokes; use a separate tracing paper sheet for each stroke group category.
4. The participant may use as many sheets as required to fulfil the need of the given set of letters.
5. The participants may use pencil first to decide the stroke group carefully, and then ink it.

6. Naming the category and writing the category name on the top right corner of the sheet.
7. The participants may give any written justification/note in the empty space at the bottom of the same sheet.
8. The given name-code on every sheet and all the sheets should be submitted in an envelope.



Figure 3.2: Participants took more than two hours to separate similar basic strokes

From here on we will term ‘participant/s’ as ‘student/s’. We received 87 tracing sheets, each containing one category of strokes extracted by six participants. Data separation, organisation and classification were carried out in two stages.

- Stage One:

The data was first scanned. Each category was cut and pasted in order to realign the stroke categories. Such minimisation of data is useful for the purposes of observation and analysis.

- Stage Two:

After the counting and separation of strokes in stage one was completed, the stroke categories were classified under the term ‘stroke similarity.’ Six participants produced 873 strokes in total and their categories ranged from 12 to 19. Without intervening in the originally made 87 categories, we rearranged them to create 14 clusters based on stroke similarity. The students showed variations in naming of the strokes and their relevance to the category they made. Therefore, we rearranged those clusters under

our labelled terms to club some of the categories. This is how data was processed/ prepared for further observation. (Ref. Table 3.1)

Table 3.1 : Shows count of strokes and categories made by each participant (Stage one)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	S.C.	C.C.
S1	44	28	3	6	5	3	2	3	4	3	8	2	3	-	-	-	-	-	-	114	13
S2	44	39	11	3	4	2	3	7	3	4	5	5	2	3	17	-	-	-	-	152	15
S3	42	27	10	5	2	3	7	2	4	9	4	4	4	7	5	7	4	4	2	152	19
S4	42	28	5	3	4	10	5	3	5	7	11	3	-	-	-	-	-	-	-	126	12
S5	42	28	22	4	9	5	12	7	13	9	5	9	5	14	-	-	-	-	-	184	14
S6	42	28	7	5	6	6	4	4	11	17	3	9	2	1	-	-	-	-	-	145	14
Stroke count of each student ranges from 114 to 184, Total number of strokes made: 873 Each student's categories range from 12 to 19, Total categories received: 87																				873	87

S-1= Student 1, A/B/C ... = Category code, example: A= Horizontal Stroke, B= Vertical Stroke etc.

Rows= Count of strokes in each category

S.C. = Count of Strokes: total number of strokes made by six students

C.C. = Count of Categories: total number of categories created by students

3.4.3 Data observations

We kept the stroke categories provided by students untouched but rearranged them in accordance to their relevant terms. It was important for the purpose of understanding and getting insights from the data.

1. Six students created categories of handwritten strokes ranging from 12 to 19 (Ref. Table 3.1)

2. All six students created ‘Vertical Stroke’ (VS) and ‘Horizontal Stroke’ (HS) as the first two categories (*Ref. Table 3.2*). However, three of them also created an additional category separating the length of VS and HS. The naming of these categories suggests individual need and variety. For example, S-4 named the category ‘Small Vertical Line’ while the others named it ‘Small Vertical and Horizontal Strokes’ (*Ref. Table 3.2, P-2*) (*Ref. Appendix II*). We clubbed the VS long and short together into a single category. This is how clubbing of categories took place, and similarity clusters were made, on the basis of the labelled term; a similar process was followed for forthcoming categories.

Counting the number of strokes or categories does not help much to understand stroke similarity, with the exception of HS and VS count (HS count range = 42:44 and VS = 27:28 with exception of S2=39 within the group (*Ref. Table 3.1*). Hence our focus is on pages 3 to 14 (*Ref. Table 3.3*) (*Ref. Appendix II*)

Table 3.2: Grouping of VS and HS: All 6 students.

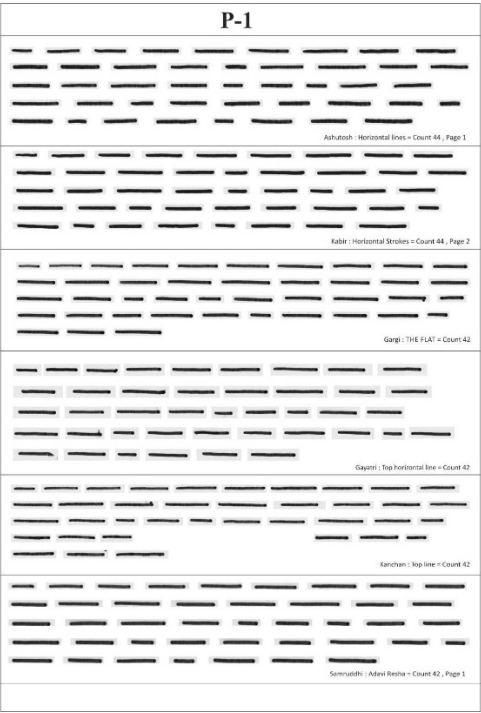
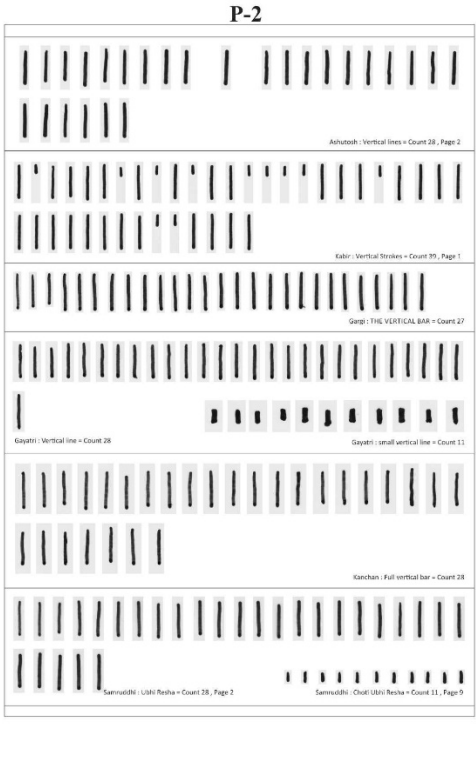
P-1  Ashutosh : Horizontal lines = Count 44 , Page 1 Kabir : Horizontal Strokes = Count 44 , Page 2 Gargi : THE FLAT = Count 42 Gayatri : Top horizontal line = Count 42 Kanchan : Top line = Count 42 Samrudhi : Adani Resha = Count 42 , Page 1	P-2  Ashutosh : Vertical lines = Count 28 , Page 2 Kabir : Vertical Strokes = Count 39 , Page 1 Gargi : THE VERTICAL BAR = Count 27 Gayatri : Vertical line = Count 28 Gayatri : small vertical line = Count 11 Kanchan : Full vertical bar = Count 28 Samrudhi : Uddi Resha = Count 28 , Page 2 Samrudhi : Choti Uddi Resha = Count 11 , Page 9
Page 1 Horizontal strokes by 6 students	Page 1 Vertical strokes by 6 students

Table 3.3: Stage two data organisation by stroke similarity among the groups made by students.

Page-3 HS + VS Joint stroke	Page-4 U shaped, Page-5 oblique	Page-6 Clockwise circular
Page-7 Anti-Clock wise circular	Page-8 S-shaped strokes	Page-9 Closed knot strokes
Page-10 to 12 Loops and overlaps	Page-13 Open knot	Page-14 Assorted strokes

3.4.4 Background for observation

Before we probed into further observation, it is important to understand the marching mannerism of Devanagari handwriting. Devanagari handwriting marches

from left to right, and therefore the sequence of strokes also generally marches in the same direction. (Ref. Chapter 2, Section 2.8)

3.4.5 Page wise observations

Page 3 and 4 (Ref. Table 3.3): Page 3 is an ideal example for the non-consideration of pen-lift. Most students looked at the letter as a whole graphic unit, rather than looking at it as a collection of strokes while dissecting the letter. (Ref. Figure 3.4)

A similar understanding was arrived at on page 4 while separating U-shaped letters. All six students separated the U-shaped stroke ranging from 3:5. A look at the original source from where these strokes are derived, clearly explains how students approached the letter. (Refer Figure 3.3)

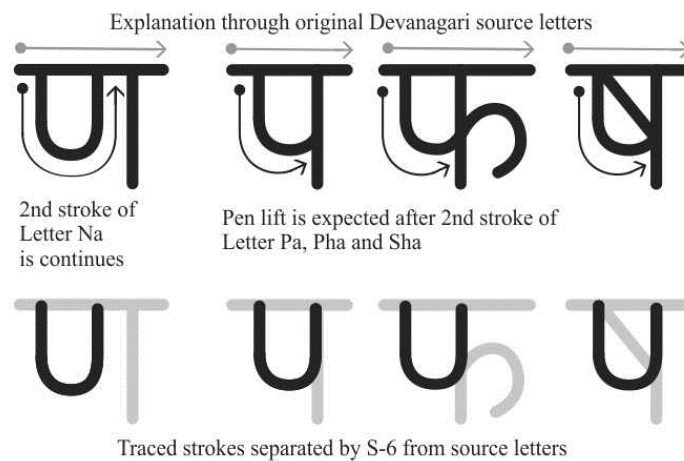


Figure 3.3: Example shows the difference between pen-lift and continuous stroke
(Ref. Table 3.3 , P-4)

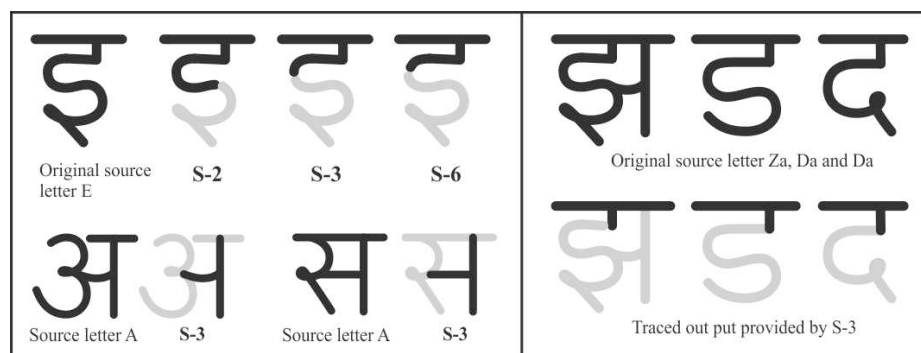


Figure 3.4: Example shows how pen-lift is not considered
(Ref. Table 3.3 , P-3)

Page 6 and 7 (Ref. Table 3.3): Clock-wise and anti-clock wise curves were separated by all six participants. However, many variations were seen on the matter of which part of the letter should be considered as a complete stroke. For example, in the clockwise stroke category, the stroke count ranged from 4 to 11 by six participants (Ref. Table 3.3, P-6), and in the anticlockwise category, it ranged from 3 to 7 strokes (Ref. Table 3.3, P-7). Except for two of six such cases, where the lower stroke of the letter ‘Ha’ was counted commonly, it was found that the continuous stroke was chopped/cut and separated. Names provided by participants clearly indicate that most of them looked at the letter as a complete form, rather than as a group of connecting strokes. For example, some strokes were named “Lower half of letter ‘a’”, “The corner bulge” etc. (Ref. Figure 3.5 & 3.6)

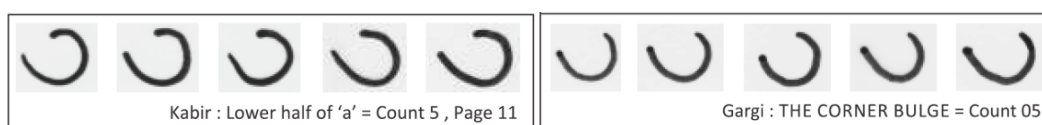


Figure 3.5: Examples of strokes chopped clock wise by participants

(Ref. Table 3.3, P-6)

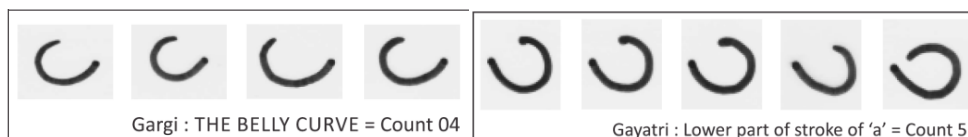


Figure 3.6: Examples of strokes chopped anti-clockwise by participants

(Ref. Table 3.3, P-7)

Page 8 (Ref. Table 3.3): The S-shaped stroke category was made by 5 out of 6 students. Student 3 (S-3) kept a small VS attached to the S-shaped stroke. Whereas student 4 (S-4) kept a continuous knot along with the S-shaped stroke. Interestingly S-5 considered ‘S’ as horizontal and considered the letter ‘La’ in the same category (Ref. Figure 3.7). Further, some students chopped the continuous strokes, while others retained the continuous stroke element. This is a sign that everyone followed their own definition of stroke in handwriting. Most of them looked at parts/units of the letter as strokes and not as continuous moving lines.

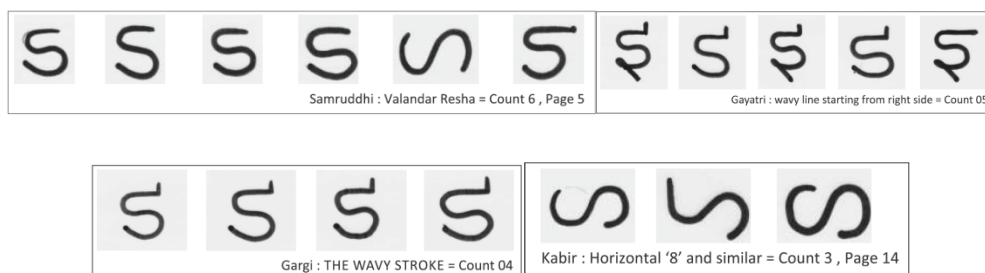


Figure 3.7: Example of S-shaped stroke separated by student participants

(Ref. Table 3.3, P-8)

The difference between part of the stroke and the complete stroke becomes very clear when we visit the next category, namely, the Closed Knot Stroke. Up until the S-shaped strokes, students sustained some directional similarity, but in this category we clearly see that all 6 students viewed the letter as a whole unit, and hence a variety of creative ways of cutting and chopping the strokes were observed. While taking a knot clock-wise, the anti-clockwise direction is also not considered within the group made by the students, since the knot is seen as a category, and is cut off as a stroke. The example below which comprises the entire closed knot data received (Ref. Table 3.4), empirically proves that all the participants looked at the Devanagari letter as a whole form and cut the most essential characteristic accordingly.

Page 9 (Ref. Table 3.3): This reveals two principles. The first is that the closed knot is the most essential character of Devanagari; and second, that the direction of the stroke is the most important aspect of handwriting activity. It clearly shows us that they looked at the letter as a whole object (more likely seen in typography) than as a structure made out of the movement of strokes in sequential order.

(Ref. Table 3.4)

Table 3.4: Categories of closed knot strokes made by all student participants.

S - 1											
S - 2											
											
S - 3											
S - 5											
											
S - 6											
											

Page 10 to 13 (Ref. Table 3.3): Since only visual/graphic similarity was followed by the students, the data received created confusion between the categories of ‘Knot’ and ‘Loop.’ This provided us insights into differentiating between what is a knot and what is a loop. A ‘knot’ in the context of handwritten stroke is a continuous line that crosses its path, while changing its direction, resulting in a closed or open knot or both. In the context of a loop, however, the stroke re-visits its original path, and stops or forms a circle in the same direction from which it began. (Ref. Figure 3.8)

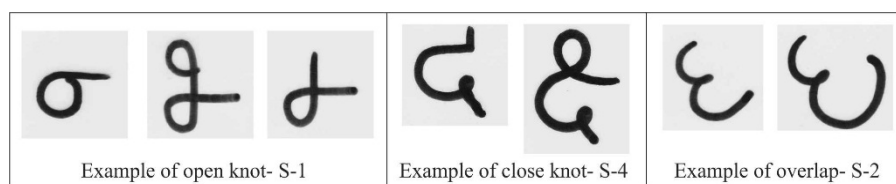


Figure 3.8: Student-4 showed a closed knot differently.

Page 5 (Ref. Table 3.3): ‘Oblique Stroke’ was considered a separate category by only 3 out of 6 students. This also means that the other 3 have considered oblique stroke either inseparable or continuous. Whereas S-1 and S-3 showed 2 oblique strokes as against S-5 who, oddly, found 13 strokes in the oblique category. This dissimilarity in data further proved that every individual looks at the Devanagari letter as a complete object as against a moving stroke line possessed of a certain directionality.

Page 12 (*Ref. Table 3.3*): In all, 3 out of 6 students classified the overlapping continuous stroke as a category. This clarified that inseparable circular strokes without changing their directionality create an overlap but not the open knot or closed knot. Here, the circular stroke just overlaps on to another circular stroke but does not form a knot. This helps one make a slim distinction between the overlap and the closed knot as categories. (*Ref. Figure 3.8*)

Page 14 (*Ref. Table 3.3*): Lastly, a category of assorted strokes was made comprising strokes that could not be fit into any of the above categories.

Insights received from data of part one exercise:

- A. A stroke in handwriting starts from point A and ends at point B; in circular or curved letters, it continues to follow a clockwise or anti-clockwise direction.
- B. In the case of Devanagari script, a letter that begins with a circular stroke, and continues further to take a straight direction, always ends in a closed knot and or overlap.
- C. There is a clear difference in an open knot and open loop letters in Devanagari.
- D. The categorisation of strokes in Devanagari letters is possible for handwriting purposes.
- E. Repetition of the same stroke was seen in more than one category. May be an instruction such as, 'do not repeat the same stroke in more than one category' is called for; otherwise it makes data observation more complex, and hinders the attempt to reach a definitive conclusion.

3.5 Extraction of strokes

Table 3.5: Inventory of deconstructed strokes from sample letters.

Table 3.5: Page-1/2

अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(1)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य	र	ल	व	श	स	ह	ळ	क्ष	ज्ञ	ष	त्र	HS-LR 47
अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(2)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य	र	ल	व	श	स	ह	ळ	क्ष	ज्ञ	ष	त्र	VS-TB 41
अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(3)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य	र	ल	व	श	स	ह	ळ	क्ष	ज्ञ	ष	त्र	DS- TLRB 10
अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(4)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य	र	ल	व	श	स	ह	ळ	क्ष	ज्ञ	ष	त्र	DS- BLRT 02
अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(5)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य	र	ल	व	श	स	ह	ळ	क्ष	ज्ञ	ष	त्र	C- Curve 11
अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(6)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य		ल	व	श		ह	ळ	क्ष	ज्ञ	ष	त्र	A-C- Curve 09
अ	इ	उ	ऊ	ए	क	ख	ग	घ	ङ	च	छ	ज	झ	(7)
ज	ट	ठ	ड	ढ	ण	त	थ	द	ध	न	प	फ	ब	
भ	म	य		ल	व	श		ह	ळ	क्ष	ज्ञ	ष	त्र	Straight + A-C Curve 07

Table 3.5: Page-2/2

अ	इ	उ	ऊ		क	ख	ग	घ	ङ	च	छ	ज	झ	(8)
ज	ट	ठ	ड	ढ			थ	द	ध	न		फ	ब	 C-Circular 10
भ	म			ल	व	श		ह	ळ	क्ष	ज्ञ			
	इ				क	ख	ग	घ	ङ	च	छ	ज	झ	(9)
	ट	ठ	ड	ढ			थ	द	ध	न			व	 A-C-Circular 13
					व	श		ह	ळ	क्ष	ज्ञ			
	इ						ग		ङ		छ		झ	
			ड	ढ			थ		ध	न				(10)
						श			ळ	क्ष	ज्ञ			 C-Curve Loop 05
	इ								ङ		छ		झ	
			ड	ढ					ध					
									ळ		ज्ञ			(11)
	इ								ङ		छ		झ	 A-C-Curve Loop 03
			ड	ढ					ध					
									ळ		ज्ञ			
	इ								ङ				झ	(12)
			इ											 S-Curve 05
									ळ		ज्ञ			
														(13)
														 Infinity Loop 01
									ळ					

On the basis of insights received from part one exercise, we separated the strokes from the basic level of Devanagari to create an inventory of deconstructed strokes (Ref. Table 3.5, Page-1 & Page-2). From this inventory, we proceeded to extract representative unidirectional similar strokes. From such a group of strokes we

eliminated the stroke that most uniquely represents its category. This filtering led us to the first level of primitives. We named these ‘Unidirectional primitives’ and ‘Multi-directional primitives’.

3.6 Unidirectional primitives

3.6.1 Stroke sorting and directional similarity clustering

Upon taking an inventory of all the basic level Devanagari strokes, we arrived at 13 different categories of unidirectional strokes. We further reduced those 13 stroke categories into 8 unidirectional primitives. We maintained directional similarity as a criterion to finalise the selection. Only unique directionality and the most representative strokes were shortlisted as unidirectional primitives. We found only one odd-looking stroke, i.e., the letter ‘La’ ऌ which comprises a double continuous loop or the infinity loop. The letter ‘La’ ऌ was found to be a good example of stroke directional similarity, even though it is dissimilar in appearance to the group to which it belongs. (Ref. Figure 3.9)

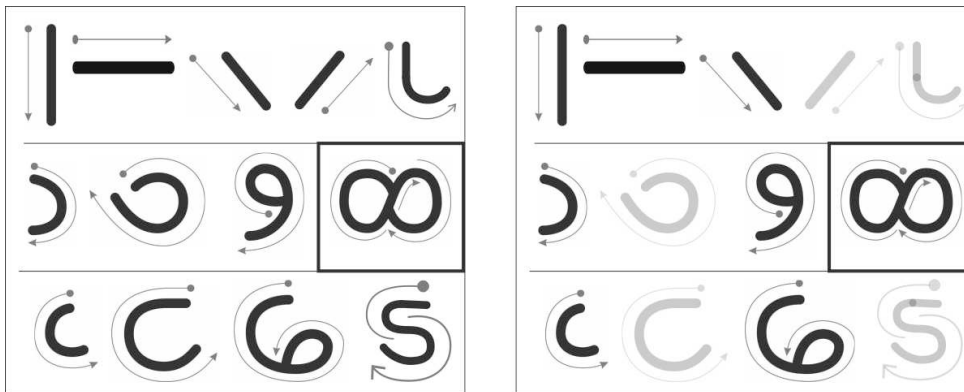


Figure 3.9: Shows omission of directionally similar strokes.

3.7 Part Two of exercise

Following are the 3 reasons that invite detailed enquiry in part two of this study:

1. Unidirectional and multi-directional loop primitives explore only the first level of this investigation. They do not cover complex areas like overlapping strokes or open and closed knot strokes.
2. Of the 8 unidirectional primitives finally arrived at, 5 matched closely with the prescribed strokes mentioned in a school book. This percentage is not very significant and points towards the need to probe in the direction of the knots and overlap aspects of Devanagari.
3. The enquiry was conducted on students as participants in part one. The three unmatched unidirectional primitives also need validation from the expert's point-of-view.

3.7.1 Procedure

In Part Two, the procedures followed were similar to those in part one, except that the subjects/participants and instructions to them were changed. For example, in part one, students between the average age group of 19 to 21 years received broad and simple instructions for deconstructing letters. The second part was conducted on experts, in the age group of 23 to 32 years. Moreover, they had experience ranging from 2 to 10 years in Typography, Calligraphy and/or related fields of graphic design. In the second part, the instructions given to them were more precise in nature. However, freedom was extended to the participants to go beyond the seven instructions provided to them (if strongly required). They were to give written justifications, over and above the seven categories they made. The primary objective of this specific instructional approach was, to ensure that the participant was more scrupulous in making stroke categories, according to directionality of strokes followed in handwritten letters.

3.7.2 Instructions

We took the prescribed basic strokes of Devanagari, from the Marathi first grade book (Ref. Figure 3.10), as our basis to plan the instructions for experts in part two, assuming that the prescribed strokes would also get validated and evaluated.



Figure 3.10: Devanagari basic strokes that exist in today's practice

(Ref. Marathi Pustak Pahile, Pathya Pustak Mahamandal. School book for 1st Standard of Marathi medium, published by Government of Maharashtra, India, Appendix I-a)

The book suggests practising eight basic strokes before learning to write. These consist of the horizontal straight line, the vertical straight line, and oblique straight lines in two directions. To cover the circularity in the Devanagari script, it suggests practising right and left side half circles and top and bottom half circles as well.

We decided to design this exercise to test the validity of these strokes by observing the experts.

Instructions were given sequentially, completing one task at a time:

Place the tracing sheet (translucent sheet) accurately on the model letter sheet that is provided. (Ref. Figure 3.11)

1. Write/draw only the vertical strokes of the entire model set of letters, considering its stroke movement. 'Stroke' here refers to strokes of any length but belonging to one category. Remove the tracing sheet after completing the entire vertical set of strokes and code the category as 'VS.'
2. By following a process that is similar to Instruction 1, separate horizontal strokes while writing/drawing on another tracing sheet and code the category as 'HS.'
3. Continue further by following a similar process to capture diagonal top left to right bottom strokes; and code the category as 'TLRB.'

4. Follow a similar process for capturing diagonal bottom left to top right strokes; and code the same as ‘BLRT.’
5. Follow a similar process to capture clockwise curve strokes; and code the category as ‘C-Curve.’
6. Follow a similar process to capture anti-clockwise curve strokes; and code the category as ‘AC-Curve.’
7. Follow a similar process to capture the full or almost fully circular stroke, and code the category as ‘AC Circular’ and ‘C-Circular.’

If the experts felt that the given 7 categories of strokes were not sufficient to justify all the letters, then, they could add more stroke categories as they deemed fit. They were also asked to code the additional categories identified by them in a logical and descriptive language in writing.

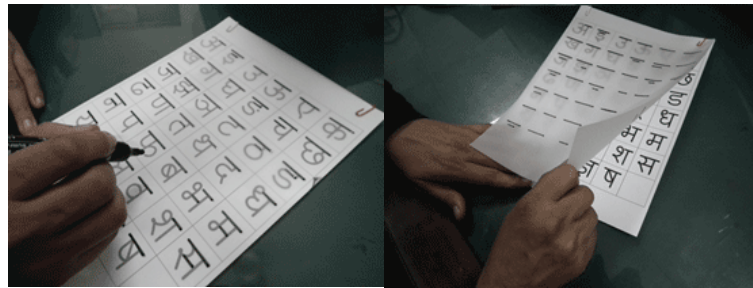


Figure 3.11: Experts’ manual process of basic strokes extraction

3.7.3 Data observations

Out of seven prescribed strokes, the first four types of strokes do not show much of a difference (*Ref. Table 3.6*). But the last three strokes that are mainly about curves and circularity show some difference within the experts’ count. However, counting the strokes and their numbers do not reveal the experts’ opinion completely.

Table 3.6: First 7 categories of stroke counts received from experts.

<i>Logically termed 7 categories.</i>	<i>E-1</i>	<i>E-2</i>	<i>E-3</i>	<i>E-4</i>	<i>E-5</i>
Horizontal – HS	45	56	67	69	48
Vertical – VS	34	41	49	48	38
Diagonal Stroke top left to right bottom – DS-TLRB	10	09	14	14	13
Diagonal Stroke bottom left to right top – DS-BLRT	01	02	03	01	02
Clockwise curve – C-Curve	12	23	22	21	13
Anti-clockwise curve – AC-Curve	20	17	26	23	11

Full or almost full circle – AC--Circular and C-Circular	06	07	25	28	16
--	----	----	----	----	----

Four out of five experts have shown an additional requirement of three to four types of stroke categories. Interestingly, all these types were dealing with the curves and circularity of Devanagari handwritten letter shapes. Hence, we focus our observation on these additional stroke categories made by them. (*Ref. Table 3.7*)

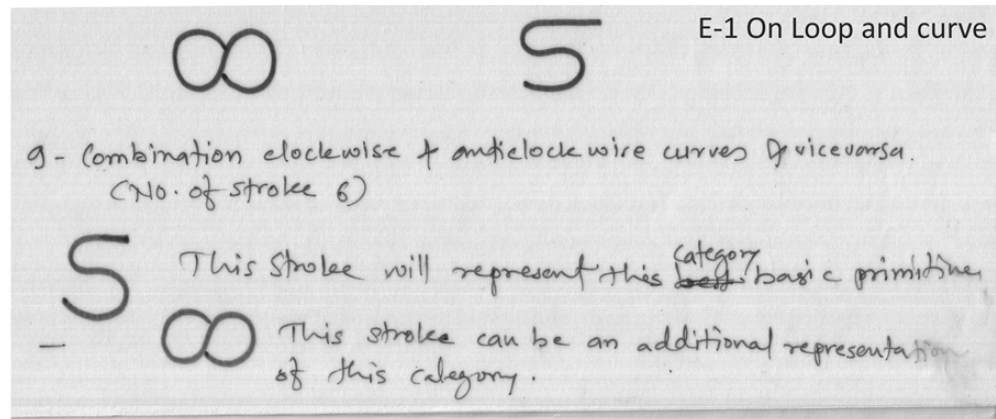
Table 3.7: Additional categories made by experts.
(over and above the prescribed 7 strokes)

<i>Terms mentioned by experts for additional categories</i>	<i>E-1</i>	<i>E-2</i>	<i>E-3</i>	<i>E-4</i>	<i>E-5</i>
Double clockwise curves (E-5)					03
Double anti-clockwise curves(E-5)					03
Full double circles(E-5)					02
All open and closed knot strokes (with sub groups) (E-5)					24
Curved stroke forming a loop (E-4)				10	
Clock and anti-clockwise combinational stroke (E-4)				09	
Free curve, e.g., French curve(E-4)				01	
Curved to straight line, clockwise or anti-clockwise (E-2)		03			
Straight to curve line any direction. (E-2)		15			
Straight to curve and to straight (E-2)		02			
Horizontal semi curved line (E-1)	04				
Clockwise knot (E-1)	11				
Anti-clockwise knot (E-1)	06				

3.7.4 Insights from Part Two of exercise

Observation on experts' additional categories:

Here, we offer glimpses of the important comments made by the experts. (*Ref. Figure 3.12*)



8- Curve stroke forming a loop (end or beginning). E-1 On Loop
(No. of strokes 10)

9 this stroke will represent this category as basic primitive

In this group 2 character goes from one single stroke which starts as straight line then creates curve and end into straight horizontal & vertical line in direction of top to bottom (U) and left to right (→) it. E-2 On Open Knot

• The letter M is written in this manner  here, which makes the curve clockwise, but it may also be written like this:  (↺ + ↗ + ↓) making the first curve anti-clockwise

E-3 On Close Knot

Figure 3.12: Experts' comments on additional categories made.

After reading select comments received from the experts, we conclude by recognising the demand for the addition of four more specific categories to the existing ones:

1. Loop of curved stroke: Single curve stroke
2. Open Knot: Combination of two strokes
3. Closed Knot: Combination of two strokes
4. Overlapping: Combination of two curved strokes

We also found this demand strongly reflected in the names assigned to these additional categories. (Ref. Table 3.8)

Table 3.8: Detailed analysis and observation of naming additional stroke categories made by experts.

No.	Frequently used words by experts, defining new stroke categories	Our observation and insight received by cross checking the visual data. (Ref- Fig.-12)
1	Curve and Circle= 07 times	All 13 different categories are about curves and circular strokes, although the words used in naming them occur 07 times.
2	Clockwise or Anti-clockwise = 06 times	More than 50% of the experts used this term. Visual data shows that most of these strokes differ from each other.
3	Double or Full Double	Point no. 3 to 3.4 all words clearly describe the joining or combinational aspects of strokes. This means the joining of two strokes but without the pen lift. This also means experts strongly need some category that includes compound strokes.
3.1	Curve to straight line	
3.2	Straight to curved line any direction	
3.3	Straight to curve and to straight	
3.4	Combinational stroke	
4	Open or close Knot, Loop	Terms used here by experts clearly point out the need for multi-directional compound stroke to be considered as a category.

3.8 Multi-directional compound primitive

By considering the experts' comments (*Refer. Figure 3.12 & Table 3.8*) we eliminated VS and HS along with the unidirectional simple and loop primitive received from inventory. We ultimately received 18 representative categories of multi-directional strokes. Further filtering them as per direction similarity and keeping their uniqueness, we received six multi-directional primitives (*Ref. Figures 3.13 & 3.14*). For example, elimination of HS (Horizontal Strokes), VS (Vertical Strokes) and unidirectional simple and loop primitive = multi-directional compound strokes further led us to multi-directional compound primitives.

अ	इ	उ	ऊ	ए	क
ख	ग	घ	ङ	च	छ
ज	झ	ञ	ट	ठ	ड
ढ	ण	त	थ	द	ध
न	प	फ	ब	भ	म
य	र	ल	व	श	स
ह	ळ	क्ष	ज्ञ	ष	ऋ

अ	इ	उ	ऊ	ए	क
ख	ग	घ	ङ	च	छ
ज	झ	ञ	ट	ठ	ड
ढ	ण	त	थ	द	ध
न	प	फ	ब	भ	म
य	र	ल	व	श	स
ह	ळ	क्ष	ज्ञ	ष	ऋ

Figure 3.13: Extraction by elimination of multi-directional compound strokes.

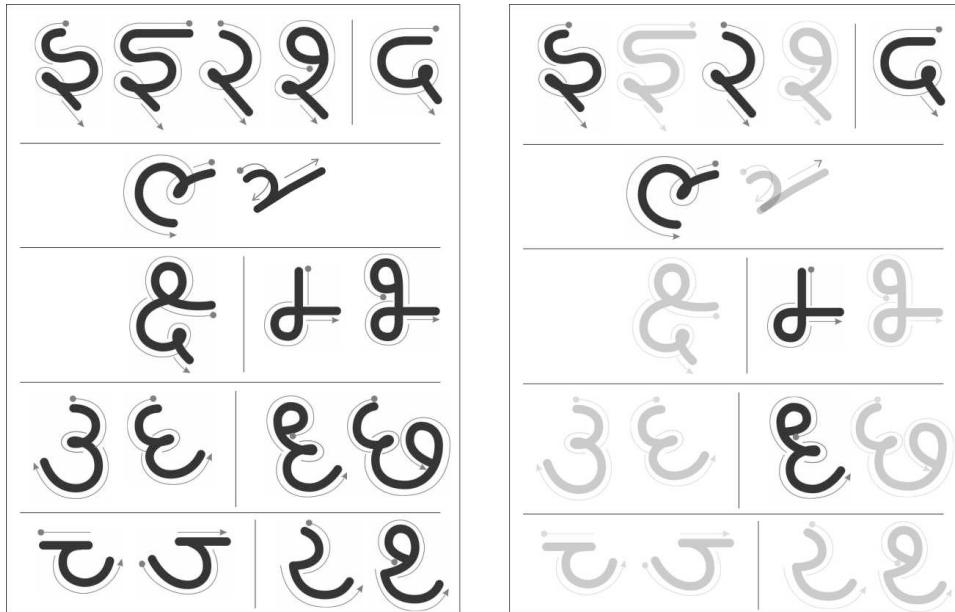


Figure 3.14: Identification and selection of multi-directional compound primitives.

3.9 Results of the exercise

Table 3.9: Details of unidirectional and multi-directional compound primitive in Devanagari handwriting.

<i>A Unidirectional strokes</i>					
		<i>Physical character</i>	<i>Direction/Movement</i>	<i>Abbreviation</i>	<i>Example</i>
	A.1	Vertical straight stroke	Top to bottom	VS-TB	
	A.2	Horizontal straight stroke	Left to Right	HS-LR	
	A.3	Diagonal straight stroke	Top left to bottom right	DS-TLRB	
	A.4	Diagonal straight stroke	Bottom right to top left	DS-BLRT	
<i>B Multi-directional single strokes</i>					
	B.1	Curved stroke	Clockwise	C-Curve	
	B.2	Curved stroke	Anti-clockwise	AC-Curve	
	B.3	Circular stroke	Clockwise	C- Circular	
	B.4	Circular stroke	Anti-clockwise	AC- Circular	
	B.5	Straight + Curved	Straight continues in anti-clockwise curve	Straight + AC Curve	
	B.6	Curve + Loop	Curve encircled with clockwise loop	C-Curve Loop	
	B.7	Curve + Loop	Curve encircled with anti-clockwise loop	AC-Curve Loop	
	B.8	Curve + Loop	Anti-clockwise continues into clockwise circle	C + AC Circular Loop/ Infinity Loop	
	B.9	Multi-directional / S Curve	Anti-clockwise continue into clockwise curve	S Curve	
<i>C Multi-directional continues compound strokes</i>					
	C.1	Overlapped continues compound	Horizontal stroke continues to overlap with clockwise + and / or anti-clockwise curve	S + C overlap Compound	
	C.1	Overlapped continues compound	Clockwise + and / or anti-clockwise continues with overlap	C + C overlap Compound	
	C.2	Close knot continues compound	Straight stroke and / or Clockwise + and / or anti-clockwise continues by taking a close knot	CK Compound (Closed Knot Compound)	
	C.3	Open knot continues Compound	Straight stroke and / or clockwise + and / or anti-clockwise continues by taking an open knot	OK Compound (Open Knot Compound)	

Most representative strokes of the above mentioned categories and classes are considered handwriting primitives of the Devanagari script (*Ref. Table 3.9*). The shortlisting of these primitives is carried out on the basis of their respective movement/directional similarities. (*Ref. Figures 3.15 & 3.16*)

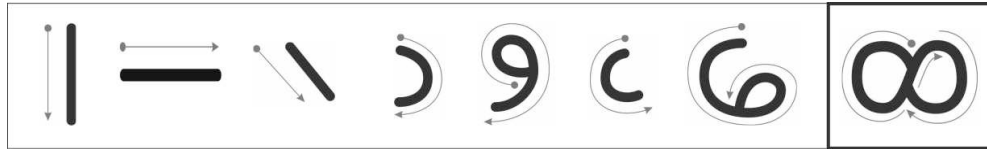


Figure 3.15: Extracted unidirectional and multi-directional primitives of Devanagari handwriting.

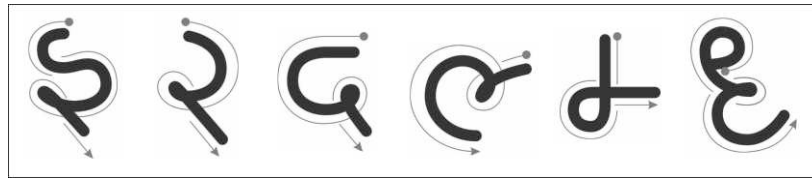


Figure 3.16: Extracted multi-directional compound primitives of Devanagari handwriting.

3.10 Findings

After separating handwritten strokes by clustering on the basis of direction similarity, the most representative stroke belonging to the cluster, is termed here as the handwriting primitive of a script.

Three categories of primitives are methodically extracted that cover the entire basic set of Devanagari letters:

1. Unidirectional primitive: A representative stroke that begins with point A and ends in point B without changing its direction
2. Multi-directional single primitive: A curved or circular stroke that changes its original direction. Such a stroke visits the same path line again by forming a loop around or encircling the path, and is, therefore, termed here as multidirectional. However such a stroke does not cross taking closed or open knot in its travelled path.

3. Multi-directional continuous compound primitive: This primitive is a compound made out of unidirectional and multi-directional strokes.

For example, the stroke that continues further by overlapping the circular stroke and/or takes a closed or open knot or both while changing its second direction. Multi-directional compound primitives were found by eliminating only HS, VS and Multi-directional single strokes from the basic Devanagari set.

3.11 Difference between stroke and primitive

The Devanagari script for handwriting is made up of specific strokes and their sequence. After extracting similar-looking strokes from the entire inventory, we found the most essential strokes by their direction that represents their category. From such a set of representative strokes, we extracted a stroke that represents unique directionality, termed here as a primitive. That is how three different categories of primitives, namely unidirectional strokes, multi-directional single stroke and multi-directional continuous compound strokes were found.

The entire purpose of our exercise was to understand the visual nature of Devanagari script that exists today. The reason behind manually extracting these primitives was the assumption that they will be useful for the acquisition of Devanagari handwriting to a new learner. Therefore, it is expected that we should look at the results within this framework. One can simply deconstruct the existing letterform in many ways, by looking at them as a complete form, but in this exercise, the logic of handwriting movement direction is maintained as a principle while deconstructing it. It also means that one is under a primary assumption, that the script shape is made up of a group of handwritten strokes, and that every handwritten stroke has a specific direction to follow, which is how strokes in handwriting are interrelated.

Another realisation is that, if the strokes follow a certain logical direction, they must follow a certain logical sequence/stroke order which ultimately affects the shape of the script/letter in context to handwriting.

3.12 Conclusion

1. By observing the handwriting movement and stroke directionality of regular and expert participants, we have learnt to deconstruct strokes for handwriting purposes.
2. A handwritten stroke is a directed line that marches till the necessary pen lift. The letter shape is made up of a group of such logically directed handwritten strokes.
3. As against our conclusion, the prescribed basic strokes for Devanagari practice mentioned in the Marathi school book were found insufficient. However, five of the obvious strokes match with the found primitives. For example, stroke numbers 1 to 6 (*Ref. Figure 3.1*) from the existing school book, match the found primitives (*Re. Figure 3.15*). But they do not consider the multidirectional aspect of the stroke and the distinct discrimination between the overlap, closed knot or open knot and encircled eye loop.

Chapter 4 Validating the Extracted Primitives

Experiment Two tests the effect of practicing Devanagari handwriting primitives on second script learners.

4.1 Background of the Experiment

'What to teach' and 'How to teach' are the two fundamental concerns in the area of teaching handwriting. A teacher teaches the letterform and 'How' here means instruction or method of teaching. Our focus is on acquisition of handwriting by the learner and how it is instructed to the learner by the teacher, books or any other learning aid. We also focus our attention on the nature of script (Dobbie & Askov, 1995) and the letterform that is exposed to a new learner via teaching, self-learning aid. We particularly attempt to investigate the nature of Devanagari script especially for new learners of handwriting.

A popular teaching, learning aid is still a printed book commonly known as handwriting practice primer. The primers of various types instruct teachers as well as the learners. Our previous study of handwriting primers has led us to find that no attention was paid to primitive (basic stroke) practice which comes considerably before acquiring the complete letter form (*Ref. Chapter 2, Section 2.10*). As rightly quoted by Farebank (1975 p.23) cited in Sassoon's PhD thesis -

“If legibility is difficult to assess in its varying conditions, how much more so is beauty. What is a good shape, a pure form, or harmony of patterning? Perhaps the answers to such awkward questions are best given obliquely; taste may be developed by acquaintanceship with the finest example of handwriting, and beauty may be found as a by-product of right method of penmanship”- Farebank (Sassoon, 1988)

Therefore we conducted an exercise to extract the primitives of handwriting for Devanagari script. It is equally important to validate these primitives empirically for which we have conducted experiment on first grade students.

It was assumed that by using extracted Devanagari basic stroke practice children will acquire Devanagari script correctly as against the prescribed basic strokes given in

the 1st grade book (*Ref. Chapter 3*). Moreover it is an unanswered question that do children really need to practice relevant basic strokes before learning to write? These assumptions and questions led to the designing of the pilot experiment before conducting the final experiment. This experiment or test validates the requirement of relevant primitives empirically for learning the script.

4.2 Pilot Experiment One and Two

The experiment validates the effect of practicing basic strokes on acquisition of handwriting by testing on Senior Kindergarten children. True experiment was conducted with Base-line test & Post-test on treatment groups. Base-line test was conducted for all children to remove background threat and to equalise the innate skill level. Group One (G1) of 3 children from Senior Kindergarten were given same amount of time for practicing the 7 general primitive strokes as against Group Two (G2) which were given 7 compound Devanagari primitives. (*Ref. Table 4.1*)

In Post-test, the children were given related Devanagari letterforms to handwrite. G2 was found successful in keeping gravity of letterforms compared to G1. From Pilot Experiment One, we learnt and designed revised pilot experiment (Pilot Experiment Two). (*Ref. Table 4.3*)

Another set of Senior Kindergarten children with English as first language (although the parental language background is non-English) was selected. An additional group - G3 was introduced in the treatment groups who would only practice full Devanagari letters instead of basic strokes. This change was introduced in Pilot Experiment Two with the requirement of measuring the effect on letter acquisition without basic stroke practice.

On the basis of inferences gained from the Pilot Experiment One, we changed the height of the sample letter and rearranged its placement; changed the size of the basic stroke, guide lines were removed on the practice sheet as well as the Post-test sheet. Along with these changes, the material and design for Pilot Experiment Two was revised together with the evaluation criteria for the jury appointed to evaluate Post-test (*Ref. Sections 4.5.2 & 4.5.4*). Through Pilot Experiment Two we tested the design

material for the Final Experiment and it has also worked as a medium for understanding the feedback from jury.

The total number of marks given by Jury-1 didn't show large variance as compared to the marks given by Jury-2. However difference was seen in proficiency of acquisition by the children. The marks given by both the juries were in same ratio. Thus, the results of Pilot Experiment Two were clear as compared to the results of Pilot Experiment One.

Moreover, significant improvement is seen in G2 in context to the understanding of overlaps, loops and knots which are the distinctive features of Devanagari script. Also, remarkable difference is seen in overall achievement in acquiring proportion and character of Devanagari letters given in Post-test.

After the results, jury expressed the modification in marking scale for more accurate evaluation. Instead of a scale of 0 and 1, the jury suggested to extend the scale i.e. from 0 to 2.

It was observed that vertical, horizontal and oblique strokes were not difficult to acquire for these group of children as they had already practiced them while learning Roman as first script which used for writing English language. The evaluation criteria were also finalised on the basis of the feedback from the jury.

4.3 Pilot Experiment One

This experiment dealt with the effect of general handwriting primitive practice as against Devanagari handwriting primitive practice on acquisition aspect of Kindergarten school children.

- General (existing in practice) Primitives:

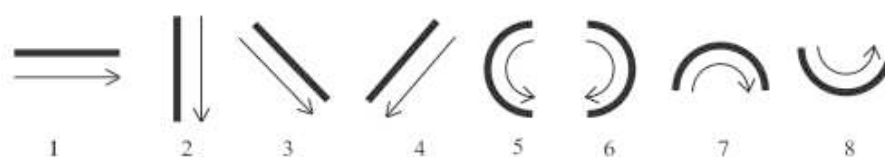
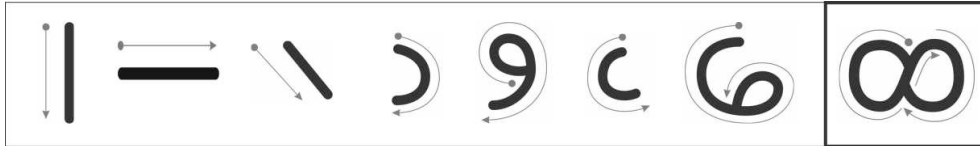


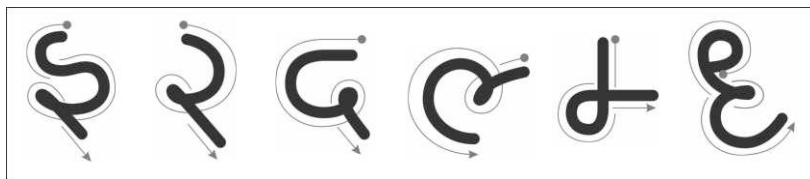
Figure 4.1: Devanagari basic strokes as seen in a first grade school book.

(Ref. Marathi Pustak Pahile, Pathya Pustak Mahamandal School book for 1st Standard of Marathi medium, published by Government of Maharashtra, India, Appendix I-a)

- Suggested Devanagari primitives:



- a. Finally extracted unidirectional and multi-directional primitives of Devanagari handwriting.



- b. Finally extracted multi-directional compound primitives of Devanagari handwriting.

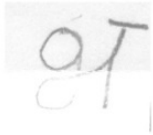
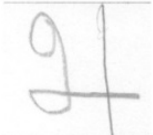
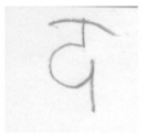
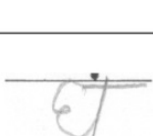
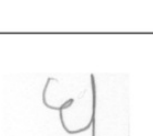
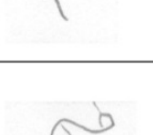
Figure 4.2: Suggested Devanagari primitives.

Table 4.1: Three steps true experiment with Base-line test, Post-test, to treatment group.

Steps	Control	T-Group	Task Description	Reason
Base line	G-1	G-2	Basic 7 strokes test.	To remove background threat. Base line test to assure that all subjects are on the similar level understanding of required skill.
Treatment	G-1	G-2	Practice session of additional Devanagari basic strokes to G-2	Suggested treatment to G-2
Post Test	G-1	G-2	Doing additional Devanagari basic strokes to G-1 and G-2	To understand by comparing G-1 to G-2 is the treatment making any significant difference?

4.3.1 Observation of Results

Table 4.2: Observation of Pilot One Result.

No	G1 General Primitive	G2 Devanagari Primitive	Observation
1. Bha			• Top line is completed • G2 ,Top line missing • Balance in upper and lower loop has achieved.
2. Da			• G1,Top line is completed • G2 ,Top line missing • Knot is merging into straight line • Basic is dominating in G1 • G2 Knot is deliberately done(almost visible)
3. Gha			• G1,V.S. is in angled, in some cases avoided • Gravity of curve achieved • Straight angle achieved in G2 • G2 ,Top line missing
4. Ie			• G1, Letter inclined and created angle • G2, almost right angle is achieved
5. Lla			• G1, entry point starts in opposite direction • G2, entry point is based on Devanagari basic stroke practice.

4.3.2 Inferences

- Experiment material: Guidelines for letters are required in practice sheets.
- A single model letter/primitive should be centrally aligned on the practice and test sheets.
- The child should be subjected to write only 5 renderings of each letter in Post-test.

- Subject background: Children from the English medium school are better subject for the experiment. As it was expected that the children should not have any background knowledge of Devanagari script handwriting.
- Minimum 5 sessions of the practice treatment is required.
- Volume and duration of the practice treatment should be more/longer than the final Post-test task.
- There must be confirmation of teacher's commitment for running all practice sessions.
- Post-test should be conducted in separate rooms and a single child at a time.

4.4 Pilot Experiment Two

Table 4.3: Three steps true experiment with Base line-test, Post-test to treatment groups.

	Base line	Treatment	Post Test
G-1 (02-S)	Write your name	Conventional 7 primitive stroke practice 5 times = 1 sheet + 7 full letters practices= 1 sheet.	7 full letters of Devanagari 5 times each = 1 sheet
G-2 (02-S)	Write your name	Devanagari 7 primitive stroke practice 5 times = 1 sheet + 7 full letters practices= 1 sheet.	7 full letters of Devanagari 5 times each = 1 sheet
G-3 (03-S)	Write your name	Only 7 full letters practices= 2 sheet.	7 full letters of Devanagari 5 times each = 1 sheet
	Reason: To remove background threat. Base line test to assure that all subjects are on the similar level understanding of required skill.	Reason: Suggested treatment to G-2. But same amount of practice to G1 and G3. Full letter practice to make them aware about letter-ness and its relevance to basic stroke practice.	Reason: To understand by comparing G-1 to G-2 is the treatment makes any effects? G-3 will show effect of directly doing full letter practice.

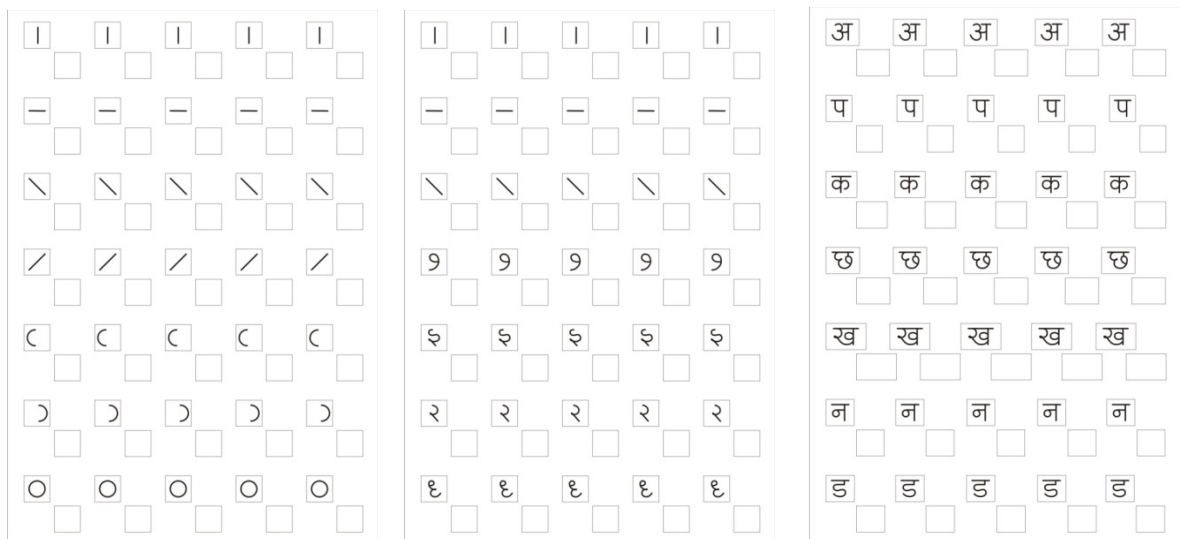
4.4.1 Choice of subject

Three groups of English medium Sr. KG children were formed wherein each group comprised of 2+2+3=07 children. Their age ranges from 5½ to 6 years. Although

these children were learning English as first language and Roman as first script in school, their parental background was checked and confirmed to be non-English.

4.4.2 Revised material design

As discussed earlier, the layout of the practice sheets as well as the post-test sheets were revised. Practice treatment for G-1 were the conventionally used 7 basic strokes (Ref. Figure 4.1) whereas G-2 was given the most frequently used 7 strokes from the suggested/shortlisted Devanagari primitives. G-3 was instructed to practice 7 complete Devanagari letters instead of any basic/primitive strokes. Alternate box arrangement was done to avoid immediate clue for copy. (Ref. Figures 4.3 & 4.4)



Practice sheet for G1

Practice sheet for G2

Practice sheet for G1, G2, G3

Figure 4.3: Practice Sheets for treatment groups

	इ		इ	
	च		च	
	घ		घ	
	द		द	
	श		श	
	क्ष		क्ष	
	भ		भ	

Figure 4.4: Common Sheet for Post-test for every group.

4.4.3 Instructions for the jury

- The evaluators were supposed to evaluate all the 5 practiced characters as a group in a row; the evaluation was done on the basis of 4 criteria where each criterion comprised of 2 marks in Pilot Experiment Two. (*Ref. Section 4.5.4 Criteria for evaluation*)
- For a child, even if 4 practiced characters were achieved correctly and consistently, it was instructed to the jury to give maximum marks. This instruction was extended to the jury in consideration of a child for reasons like fatigue, forgetting unknowingly, hurrying up for the next letterform, etc.
- In the practice treatment all the letterforms were not included which were given finally in the Post-test. The jury was expected to consider this while evaluating.

E.g. In point number one mentioned in the criteria for evaluation, the language used is “Straightness of a line” and not 90 degree to ‘x’ or ‘y’ axis, however geometry can be

considered as a model to understand how much a child's handwritten character is identical to the given sample. The prescribed evaluation scale does not allow fractional measurements like 0.2, 0.5 etc. Therefore evaluator is expected to use his judgement, for instance if the rendered letter is 80% close to geometrical definition of the provided sample letter/model, then the evaluator is expected to give full marks. In case if the rendering doesn't match accordingly, then the attempt is not liable for any point/marks.

4.4.4 Criteria for evaluation

1. Straightness of line achieved? In HS, VS, DS = Y or N (out of 01 mark)
2. Curve/circular strokes are achieved? (appropriate in context to basic letter structure) Achievement in case of curves/semi-circular/circular strokes? = Y or N (out of 01 mark)
3. Knot/overlap/loop is correctly/confidently achieved? = Y or N (out of 01 mark)
- 3.1 Interrelated proportions of group of strokes within the letter form are achieved? = Y or N
4. Overall proportionate copy of letterform including overall balance/gravity of letterform is achieved? Is the handwritten character close to the sample letter? = Y or N (out of 02 marks)

In point number 4 the jury has a scope to give 01 out of 02(01/02) or 02 out of 02(02/02) or nil.

4.4.5 Method of evaluation

1. It is always better to have an overview of all the papers visually first. This will allow one to make gross (overall quality wise) categories e.g. A, B, C, D. For example, if one has to evaluate 8 children's practice sheets then he might have one in group A, three in group B, two in group C and two in group D, from which one sheet from each group could be selected for detailed evaluation/marking. This procedure allows making comparative decisions one more time.

2. Evaluate only 4 pages a day e.g. A, B, C, D which would avoid fatigue of over working. And then keep previously marked pages in sight while marking the present day's group of practice sheets. This will allow one to compare their own decisions, allow re-shuffling the order for improved accuracy in marking.
3. Mark all the papers initially with pencil and not with pen. Only while submitting them, check all the sheets and then ink your markings (preferably with blue ink pen).
4. Sign on the back side of each paper and date it.

4.4.6 Results

Table 4.4: Analysis and Result of Pilot Experiment Two

Jury-1	G-1	G-1	G-2	G-2	G-3	G-3	G-3
Straightness of line	35	33	35	35	35	35	34
Curve/circular strokes	35	24	35	35	35	35	33
Knot/overlap/loop	35	21	35	34	31	30	25
Overall proportion	43	25	65	65	61	53	49
TOTAL	168	103	170	169	162	157	145
Jury-2	G-1	G-1	G-2	G-2	G-3	G-3	G-3
Straightness of line	25	13.5	35	32.25	24	25	33
Curve/circular strokes	6	2.5	33	25	22	13	9
Knot/overlap/loop	8	1	19	20.25	14	14	17
Overall proportion	22	6	47	43.5	34	38	25
TOTAL	61	23	134	121	94	90	84

4.4.7 Observations

- Jury-1 and Jury-2 emphasised over requirement of fractions while marking features of a letterform as against overall proportions.
- According to Jury-1, in some cases all the criteria are achieved along with overall proportions but letter looks totally like any other letter than sample letter that is expected to copy. Therefore, identity retention should be added as one more criterion.

- Although while marking, two different attitudes are seen by juries but they differ only in marking percentage and are not contradicting to their core opinion.

4.4.8 Conclusion

- It is inferred that the data requires a qualitative method of analysis.
- It can be assumed that an increase in the number of subjects may show significant difference statistically.
- It can also be assumed that increasing fractions in the marking scale will allow a more detailed enquiry of the effect.

4.5 Final experiment

The Final Experiment was conducted on 3 groups, each group consisting of 13 children, of Senior English Medium Kindergarten school stationed in Mumbai. The reason of selecting an odd number of children in a group is as it was experienced that lower age children remain absent during practice session/post-test and expecting a continuous week long presence as per our schedule seemed unrealistic. Therefore we took 13 children per group instead of required minimum number of children (10 per group for better counting).

4.5.1 Improved experiment design

Subject's background, age group of Children remains the same. From the post-test test we replaced the letter 'Ksha' to letter 'Shra'. The letter 'Shra' has a diagonal upward stroke moving from bottom left towards the top right hand side. This movement of stroke is unique and not found in any Devanagari basic set of letter. More over letter 'Shra' is a conjunct consonant compound letter and ideally should be learnt in higher class. The extracted compound primitive stroke does not consider this unique movement hence it was selected as one of the complex letter for post-test. The other selected letters were selected on the basis of the practiced basic strokes.

4.5.2 Improved evaluation criteria

Our jury remains the same who evaluated the Pilot Experiment Two. Therefore as per their strong suggestion, we added new criterion termed as Identity of Letter. Also, every criterion will be marked out of five marks to enable evaluation of the difference more critically in micro aspect about fulfilling the need of criteria. Every attempt of letter therefore will be marked 5 criteria X 5 =25 marks. And all five attempts will receive 25 X 5 =125 marks. Entire post-test sheet consisted of such 7 letters therefore 125 X 7 = 875 marks were given for post-test of every child. 10 children per group, and likewise 3 groups. These numbers remained constant.

4.5.3 Marking Sheet design

G-1-student 03						G-1-student 03					
इ	Atmpt-1	Atmpt-2	Atmpt-3	Atmpt-4	Atmpt-5	च	Atmpt-1	Atmpt-2	Atmpt-3	Atmpt-4	Atmpt-5
Straightness of line	4	4	4	4	4	Straightness of line	5	4	4	5	5
Curve/circular strokes	5	5	5	5	5	Curve/circular strokes	4	4	4	4	5
Knot/overlap/loop	4	4	5	4	4	Knot/overlap/loop	4	4	4	4	5
Overall proportion	5	4	4	4	4	Overall proportion	4	4	4	5	4
Identity of Letter	5	5	5	5	5	Identity of Letter	5	4	5	5	5
AVERAGE						AVERAGE					

Figure 4.5: Example of marking sheet design for jury.

(See Appendix IV for the entire data received from jury one and two)

4.5.4 Statistical analysis of result (Jury-1)

Table 4.5: Statistical analysis of result: Final Experiment (Jury-1)

IES Experiment Jury -1 result			
Students	Group A	Group B	Group C
1		1.44	2.257142857
2	2.977142857	1.474285714	2.062857143
3	2.262857143	1.874285714	4.508571429
4	2.874285714	3.257142857	3.771428571
5	2.56	2.702857143	3.405714286
6	2.2	2.811428571	2.377142857
7		1.457142857	3.988571429
8	2.291428571	2.2	2.177142857
9	2.257142857	2.131428571	2.577142857
10	2.217142857	2.954285714	1.794285714
11	0.754285714	2.697142857	
12		2	1.868571429
13	2.245714286	1.388571429	3.908571429
Mean	2.264	2.183736264	2.891428571
STDEV	0.570552471	0.621550585	0.917633751
SEM	0.180424533	0.172387116	0.264898047
N	10	13	12

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Group A	10	22.64	2.264	0.361700136		
Group B	13	28.38857143	2.183736264	0.418518891		
Group C	12	34.69714286	2.891428571	0.918601855		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	3.605906257	2	1.802953129	3.138615743	0.056931333	3.294536816
Within Groups	18.38214832	32	0.574442135			
Total	21.98805458	34				

IES Experiment Jury -t-Test result		
t-Test: Two-Sample Assuming Equal Variances		
	Group A	Group C
Mean	2.264	2.891428571
Variance	0.361700136	0.918601855
Observations	10	12
Pooled Variance	0.667996082	
Hypothesized Mean Difference	0	
df	20	
t Stat	-1.792902268	
P(T<=t) one-tail	0.044063712	
t Critical one-tail	1.724718243	
P(T<=t) two-tail	0.088127423	
t Critical two-tail	2.085963447	

IES Experiment Jury -1 result		
t-Test: Two-Sample Assuming Equal Variances		
	Group B	Group C
Mean	2.183736264	2.891428571
Variance	0.418518891	0.918601855
Observations	13	12
Pooled Variance	0.657689004	
Hypothesized Mean Difference	0	
df	23	
t Stat	-2.179849345	
P(T<=t) one-tail	0.019879854	
t Critical one-tail	1.713871528	
P(T<=t) two-tail	0.039759708	
t Critical two-tail	2.06865761	

IES Experiment Jury -1 result		
t-Test: Two-Sample Assuming Equal Variances		
	Group A	Group B
Mean	2.264	2.183736264
Variance	0.361700136	0.418518891
Observations	10	13
Pooled Variance	0.394167996	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.303939014	
P(T<=t) one-tail	0.382082738	
t Critical one-tail	1.720742903	
P(T<=t) two-tail	0.764165476	
t Critical two-tail	2.079613845	

Significance divided by 3 (Number of Groups) =Bonferroni Correction Test $0.05 / 3 = 0.016666667$			
Pair Group	P(T<t) two tail	$0.05 / 3 =$	
G-A to G-B	0.088127423	< 0.016666667	FALSE
G-B to G-C	0.039759708	< 0.016666667	FALSE
G-A to G-C	0.764165476	< 0.016666667	FALSE

4.5.5 Statistical analysis of result (Jury-2)

Table 4.6: Statistical analysis of result: Final Experiment (Jury-2)

IES Experiment Jury-2 Results			
Students	Group A	Group B	Group C
1		3.771428571	3.862857143
2	4.542857143	4.171428571	4.057142857
3	4.36	4.28	4.982857143
4	4.834285714	4.885714286	4.891428571
5	4.72	4.611428571	4.805714286
6	4.491428571	4.702857143	4.228571429
7		4.291428571	4.986666667
8	4.485714286	4.462857143	4.228571429
9	4.228571429	4.365714286	4.628571429
10	4.434285714	4.845714286	4.034285714
11	3.233333333	4.834285714	
12		3.817142857	4.022857143
13	4.466666667	3.308571429	4.988571429

Mean	4.379714286	4.334505495	4.476507937
STDEV	0.414815873	0.456865935	0.424191255
SEM	0.131176297	0.126711812	0.122453468
N	10	13	12

IES Experiment Jury-2 Results						
Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Students	13	91	7	15.16666667		
Group A	10	43.79714286	4.379714286	0.191191343		
Group B	13	56.34857143	4.334505495	0.226120356		
Group C	12	53.71809524	4.476507937	0.196296241		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	64.40070241	3	21.4669008	5.008359307	0.004491999	2.816465817
Within Groups	188.593425	44	4.286214205			
Total	252.9941274	47				

IES Experiment Jury-2 Results		
t-Test: Two-Sample Assuming Equal Variances		
	Group A	Group B
Mean	4.379714286	4.334505495
Variance	0.191191343	0.226120356
Observations	10	13
Pooled Variance	0.211150779	
Hypothesized Mean Difference	0	
df	21	
t Stat	0.233902201	
P(T<=t) one-tail	0.408663042	
t Critical one-tail	1.720742903	
P(T<=t) two-tail	0.817326084	
t Critical two-tail	2.079613845	

IES Experiment Jury-2 Results		
t-Test: Two-Sample Assuming Equal Variances		
	Group B	Group C
Mean	4.334505495	4.476507937
Variance	0.226120356	0.196296241
Observations	13	12
Pooled Variance	0.211856649	
Hypothesized Mean Difference	0	
df	23	
t Stat	-0.770667525	
P(T<=t) one-tail	0.224374365	
t Critical one-tail	1.713871528	
P(T<=t) two-tail	0.44874873	
t Critical two-tail	2.06865761	

IES Experiment Jury-2 Results		
t-Test: Two-Sample Assuming Equal Variances		
	Group A	Group C
Mean	4.379714286	4.476507937
Variance	0.191191343	0.196296241
Observations	10	12
Pooled Variance	0.193999037	
Hypothesized Mean Difference	0	
df	20	
t Stat	-0.513246937	
P(T<=t) one-tail	0.306700848	
t Critical one-tail	1.724718243	
P(T<=t) two-tail	0.613401695	
t Critical two-tail	2.085963447	

Significance divided by 3 (Number of Groups) =Bonferroni Correction Test $0.05 / 3 = 0.016666667$			
Pair Group	P(T<t) two tail	$0.05 / 3 =$	
G-A to G-B	0.817326084	< 0.016666667	FALSE
G-B to G-C	0.44874873	< 0.016666667	FALSE
G-A to G-C	0.613401695	< 0.016666667	FALSE

4.5.6 Conclusion

Post ANOVA T testing of treatment groups was conducted to understand the interrelation between them. The results brought forth by both the juries informed that Group B gained significantly higher marks as compare to Group A and C. This was contradictory to the results received from the earlier conducted pilot experiments. Apart from the percent differential, the opinion of both the juries did not differ. Therefore we decided to enquire the unexpected results firstly through data received from juries and secondly confirming it by revisiting doubtful cases (mostly children from Group C). (*Refer 4.6.3 and 4.6.4 - Statistical analysis Jury-1 and Jury-2*) (*Ref. Tables 4.5 and 4.6*)

4.5.7 Doubtful cases identified

Refer Appendix IV

Table 4.7: Final Experiment-Highest Marks in Post Test: (Doubtful cases identified)

Group	Code	Name of student	Marks	M/F	DOB
G-1	G-1-S-02	Sameera Sawant	521	F	04/07/2007
G-2	G-2-S-04	Shrushti Koth	570	F	20/06/2007
G-3	G-3-S-03	PaavaniGawade	786	F	23/06/2007
G-3	G-3-S-04	Nikhil Dange	660	M	
G-3	G-3-S-05	Parth Mane	596	M	02/05/2007
G-3	G-3-S-07	Harsh Ksahilkar	698	M	19/06/2007
G-3	G-3-S-13	Saloni Suryavanshi	680	F	19/12/2007

Table 4.8: First Final Experiment-Lowest Marks in Post Test

Group	Code	Name of student	Marks	M/F	DOB
G-1	G-1-S-11	Dhruv Misal	132	M	14/05/2008
G-2	G-2-S-01	Swayam Mahindrakar	252	M	
G-3	G-3-S-10	Arya Patil	314	M	

: (cases also to be checked)

4.5.8 Confirming the background threat

A surprise test was conducted on the children who received unexpectedly higher marks. Every child was interviewed separately and instructed to write his/her name in Devanagari script. While children were working on the given task, a video was recorded of their activity. While working on the task they have been asked questions like ‘who taught you to write?’ or ‘from where did you learn this?’ (This means writing in Devanagari Script). Some of the children clearly answered that they learnt it from their parents. The results of the written test and their answers confirmed that they already knew how to write basic Devanagari letters before participating in the experiment. This confirmed the background threat of pre-requisite information of the students in context to Devanagari script.

4.5.9 Inferences

Analysis of the results of the Final Experiment and feedback received from the children of G-3 suggested to repeat the same experiment design on children with no prior knowledge of Devanagari script. Repetition of the experiment was conducted with an assumption that the experiment would either get us the expected results, or it will validate the results that were already received. However, availability of children with non-Devanagari background was a challenge in a cosmopolitan city like Mumbai, as Mumbai is surrounded by Devanagari and Roman script cultures. Such circumstances keep the background threat i.e. prior knowledge of Devanagari script of the children.

4.6 Repeated Final Experiment

As observed and inferred from the Final Experiment, a subjects' background considerably affects handwriting acquisition. Thus, subjects with non-Devanagari background were required. Therefore we decided to shift our experiment in the neighbouring state of Karnataka.

4.6.1 Experiment on Kannada medium school

In Bangalore, government schools teach only Kannada as the first script till sixth standard. Therefore children do not learn any script other than Kannada until 4th standard. Our requirement as per age group was 1st standard children. Therefore we found such children fit for our experiment.

4.6.2 Kannada script structure

Kannada script is basically curvilinear in nature. All the letters are separate and disjoint. It has open and closed loops. Most importantly, it has almost negligible presence of horizontal and vertical strokes like in Devanagari. Some of the letters also have bottom to top anti-clock movement which is rarely used in Devanagari script. Devanagari script is more square and circular with predominant and connected top line. The earlier final experiment was a failure, solely due to the reason of the

unknown background of the children. Therefore it was decided to conduct the experiment on Kannada medium school students where Kannada is taught as the first language and first script.

ಅ	ಆ	ಇ	ಈ	ಉ	ಊ	ಋ	ೠ	ಎ	ಏ	ಓ	ಔ	ಒ	ಋ	ಌ	಍
a	aa	e	ee	u	uu	ru	ruu	ae	aee	i	o	oo	ou	am	aha

ಕ	ಖ	ಗ	ಘ	ಜ	ಙ	ಚ	ಛ	ಝ	ಞ	ಟ	ಠ	ಡ	ಢ	ತ	ಥ
ka	kha	ga	gha	jna	cha	chha	ja	jha	nya	ta	tta	da	dda	nna	tha

Figure 4.6: Example of Kannada handwritten letter forms.

4.6.3 Statistical analysis

One way analysis of variance (ANOVA) was conducted to evaluate the relationship between the three pre-practiced (treatment) groups. The relationship between these groups will make us understand the effect of three different types of practices on acquisition of Devanagari handwriting.

The practice of basic strokes was considered as the independent variable whereas the marks the children attained in Post-test for each attempted letter were considered as the dependent variable. Three different pre-practices received were, Group 'A' practiced conventional basic strokes, Group 'B' was instructed to practice extracted Devanagari basic strokes and group 'C' did not practice any basic strokes, instead, they practiced complete letters. The ANOVA was significant $F(2, 26) = 5.40$, $p = 0.01$. (see Appendix IV)

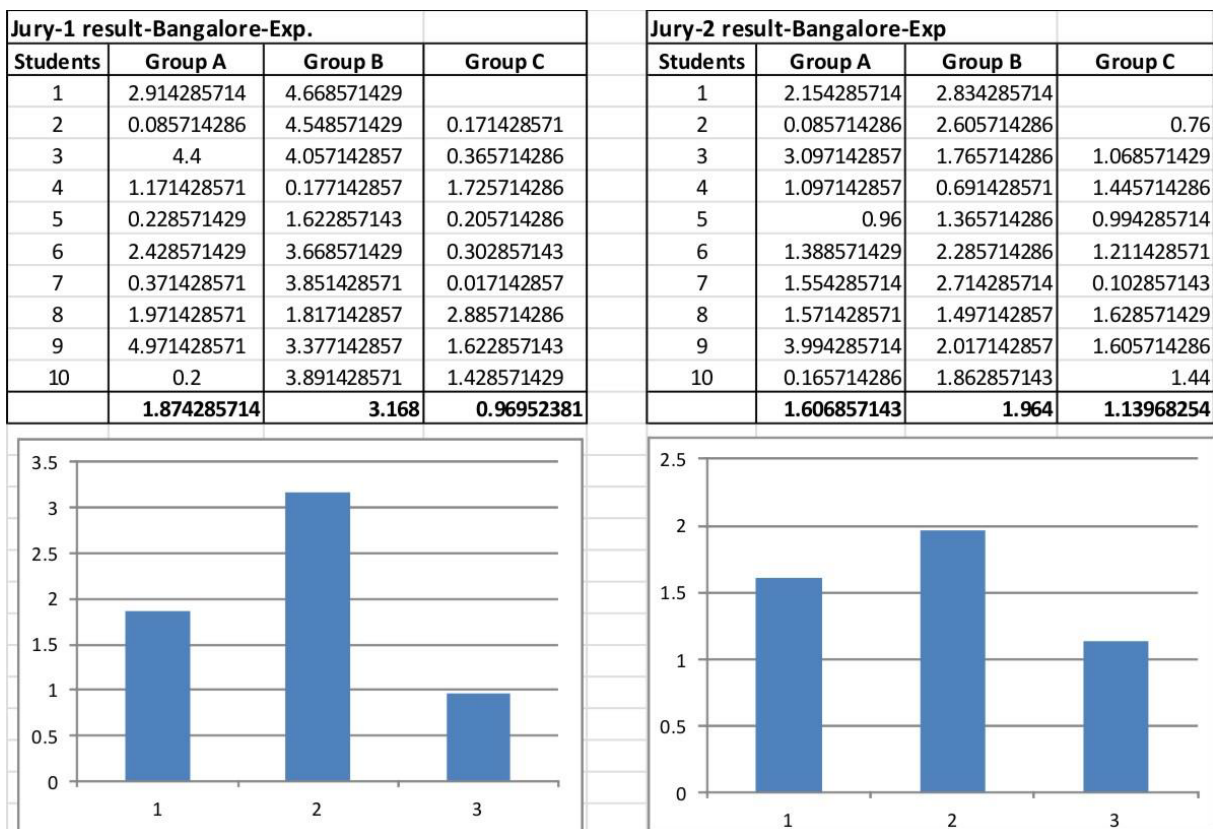
Follow up test (Post ANOVA testing) was conducted to evaluate pairwise difference among the individual group mean. There was a significant difference in the means between the groups that received Devanagari basic stroke practice (G-B) as against

no basic stroke practice group (G-C). But no significant difference was found between other groups (E.g. G-A to G-C and G-A to G-B) (see Appendix IV)

4.6.4 Comparison of results

Jury-1's marks giving tendency looks lenient compared to Jury-2. However, numerically they differ, but ratio of percentage appears similar. While evaluating Group B, they differ more as compared to group A and C. Both the results show symmetrical trend. E.g. Group C (G-C) is lowest, Group A (G-A) is between G-B and G-C and Group B (G-B) received the highest marking. Bangalore results as against Mumbai results, the symmetrical trend among the two different juries marking is seen significantly confident.

Table 4.9: Comparison of results received from two different juries.



4.6.5 Conclusion

1. The system of manual extraction of primitives of letterform for handwriting purposes is possible.
2. Basic strokes practice proves effective on correct acquisition of handwriting learning.
3. Devanagari basic and compound stroke practice was found conducive for correct acquisition of handwritten Devanagari script.
 - 3.1 Thus we can generalize that 'X' basic strokes of 'X' script helps in acquisition of that 'X' script.
 - 3.2 This also means that, insufficient basic strokes primarily extracted from 'Y' type of script will not be effective to acquire 'X' type of script.
 - 3.3 Children learning more than one script simultaneously at an early age, are required to take combined basic stroke practice for more than first script/mother script.

Chapter 5 Conclusion

5.1 Summary of Major Findings

Scientifically, 'learning to write' is a gradual, consistent and prolonged process. It is a multi-sensory and inter-disciplinary phenomenon. It begins with visually recognizing the letterform along with its associated phonetic value which makes the child or the learner recognize and remember the letterform. After a repeated sequence of memorizing the shape and form of the letter together with its phonetic value, the child/learner acquires the ability to pronounce the spoken value of the letter/s (word) by seeing it. This recollection of earlier experience completes one's cycle of seeing, recognizing and saying, which is generally termed as 'reading'. Reading consists of development of vocal cords and related tongue/muscular maturity of movement. Similarly, writing demands developed fine motor activity of child's/learner's finger movement. But apart from these physical aspects, the visual of the letterform presented as a model which is integrated in this process is generally found to be overlooked. To see and draw the visible shape of the letter is unavoidably important in the process of handwriting acquisition. Hence, it invites the specialized graphical or morphological research enquiry. Therefore, we also claim that it is a graphic design research issue as well.

We began our enquiry by probing into the available research in context of handwriting as an activity. Research in handwriting began in the early 19th century. We studied a body of continuous research of two decades (1970s to 1980s) conducted in America (Dobbie and Askov, 1995). This research shed light on many issues related to handwriting as a multi-sensory and inter-disciplinary activity which guided us to categorise our research into four parts namely-

1. Material and Postural aspects
2. Educational aspect (teaching and learning handwriting)
3. Language aspect
4. Script aspect (Graphic / morphology of letterforms)

We found that issues related to the first three out of the four above mentioned aspects are enquired thoroughly whereas the graphical/morphological aspect has not been investigated sufficiently.

Most of the available research that we referred was 'Roman/Latin centric'. (*ref. 2.6*) It was also found that the Indian researchers have focused their enquiries more on the 'Language acquisition' as compared to 'Handwriting acquisition'. While probing into Roman/Latin centric handwriting research literature, we discovered that handwriting research conducted so far is script specific and is of less use to different scripts of the world, especially in its morphological aspects. Moreover, within the respective script culture, micro level issues about morphological aspects still remain unresolved. For example, which hand to follow while learning handwriting? 'Print' or 'Cursive hand', is still a debate in spite of three decades of handwriting research in America. 'Print hand' emphasises on the readability of the reader, whereas 'Cursive' is more concerned about the fluency of the writer.

The Indian researchers have also pointed out the need for a scientific enquiry about the graphical/morphological aspect of Indian scripts for handwriting learning purposes (Gupta R., 2012). This sets the research scope for all Indian scripts in context to handwriting acquisition. We took Devanagari script for our research enquiry as Devanagari is the most utilised script in India.

The micro level enquiry into Devanagari handwriting marching mannerism discloses that basic level morphological categorisation of Indian scripts is not enough if one wishes to conduct research into handwriting acquisition. As the morphological aspect of each script always remains unique, it should be individually analysed.

It has long been established by practice based calligraphers that basic stroke practice, necessary to formulate a letterform is essential to acquire calligraphy skills (Jackson, 1894). As our enquiry is closely related to the preliminary aspects of educational psychology, we focused on those areas of the theories that dealt with cognitive processing of a child or a new learner that results into skill acquisition. On the grounds of Bruner's theory of learning, if the complex task is dissected into simplified bits, it becomes easy for the learners to approach the problem solving stage themselves.

Handwriting practice primers are still an important media in India. These primers are either used as reference or models for practice by teachers or learners for handwriting acquisition. On the premise of this background study, we assessed the existing primers of Devanagari and the following observations were inferred:

Available & existing Devanagari handwriting primers are essentially instructions for the ideal movement of hand. These Devanagari primers did not cover any method of teaching basic strokes⁵ or any kind of doodling stage that is fundamental for handwriting readiness. Only one book (1st standard) included one page about the 8 basic strokes. (*Ref Figure 3.1 & Appendix I-a*)

Variations in the order of strokes, pen lifts etc., were found as the primers were not scientifically designed. (*Ref. Chapter 2, Section 2.10*)

In conclusion, the primer study made us realise that basic stroke practice is missing in majority of primers for Devanagari script. On the other hand, non-standardised practice in context to sequence of strokes was identified through the collected data of primers.

Are the basic strokes present in the existing school book (*Ref. Figure 5.1*) sufficient to justify the core graphic complexity of Devanagari script for handwriting?

To find an answer to this question, we designed and conducted the exercise to manually extract Devanagari primitives/basic strokes. A practical exercise was indigenously designed since there was no specific existing method for extracting handwriting primitives of scripts. The manual extraction of basic strokes exercise was conducted on students and experts. The entire data of manually extracted strokes was analysed with regards to shape and movement similarity.

Thus, Exercise One (Chapter 3 Manual Extraction of Devanagari primitives) led us to the following conclusions:

Handwriting is a manual activity. Therefore, deconstructing the letterforms manually by the learned test subjects was found constructive, practical and justifiable. With this understanding, we designed the manual extraction exercise involving students and experts. Writing is a stroke-by-stroke sequential process and hence is dynamic

⁵ 'Basic strokes' and 'Primitive' should be read as synonymous terms.

which occurs with certain automaticity with grown-ups. Thus, decoding basic strokes from complete written letterforms in the specific writing sequence is essential. To achieve this, the technique of using translucent paper overlaid on model letterform sheet was found successful. (Ref. Chapter 3, Figure 3.11)

Through broad instructions such as – ‘separate the basic strokes from the given model letterform’ the data obtained was incomprehensible. Whereas specific instructions such as – separate vertical strokes (VS), horizontal strokes (HS), clockwise curved strokes and anti-clockwise curved strokes, helped us to discover the combinational strokes as outliers but which were also responsible for the graphic character of Devanagari script. Hence, the design of the instructions is the important segment of our experiment design.

As against the extracted Devanagari primitives, the prescribed basic strokes for Devanagari practice mentioned in existing school books were found insufficient. However, five fundamental strokes amongst the extracted Devanagari primitives match with basic strokes in existing school books as well.

The results of this exercise provided us with two levels of Devanagari primitives namely-

1. Unidirectional
2. Multi-directional compound primitives

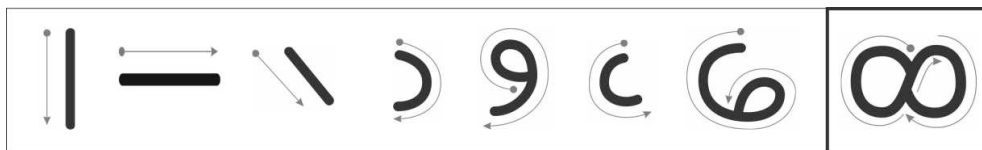
- General (existing in practice) Primitives:



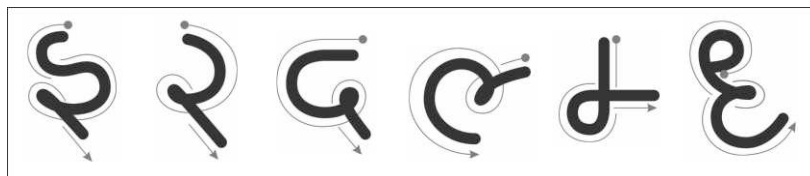
Figure 5.1: Devanagari basic strokes as seen in a first grade school book.

(Ref. Marathi Pustak Pahile, Pathya Pustak Mahamandal School book for 1st Standard of Marathi medium, published by Government of Maharashtra, India, Appendix I-a)

- Suggested Devanagari primitives:



a. Finally extracted unidirectional primitives of Devanagari handwriting.



b. Finally extracted multi-directional compound primitives of Devanagari handwriting.

Figure 5.2: Suggested Devanagari primitives

We discovered, as the structure of Devanagari script is complex, it demands multi-directional compound primitives.

Although, two levels of primitives were extracted using the new manual method, it was necessary to test the efficiency of these primitives. The unavailability of an established method to measure the effect of the basic strokes practice in acquisition of a new learner, led us to design an indigenous experiment (*Ref. Chapter 4*). This experiment design was developed through a series of pilot experiments.

The Final Experiment (*Chapter 4*) included 3 groups of 13 Sr. KG students in each group which were selected from an English medium school stationed in Mumbai. Three different types of practice treatments were given to them. Group-1 received practice of the basic strokes as prescribed in the school book. Group-2 received practice of the Devanagari basic strokes extracted from our exercise (*Ref. Figures 5.1 & 5.2*). Group-3 received complete letter practice without any basic strokes. This treatment was given a duration of 5 days. After practice session for 5 days, on the 6th day we conducted common post-test for all three groups. Post-test included those letters which were not given in the practice treatment. The Post-test sheets were then evaluated by two different juries on the basis of the system of evaluation developed and provided by us.

The series of pilot experiments enabled us to fine tune the selection of the test subjects (school children), procedure of conduct, design of the material for test, and the evaluation criteria for Post-test. (*Ref. Figure 5.3*)

G-1-student 03						G-1-student 03					
इ	Atmpt-1	Atmpt-2	Atmpt-3	Atmpt-4	Atmpt-5	च	Atmpt-1	Atmpt-2	Atmpt-3	Atmpt-4	Atmpt-5
Straightness of line	4	4	4	4	4	Straightness of line	5	4	4	5	5
Curve/circular strokes	5	5	5	5	5	Curve/circular strokes	4	4	4	4	5
Knot/overlap/loop	4	4	5	4	4	Knot/overlap/loop	4	4	4	4	5
Overall proportion	5	4	4	4	4	Overall proportion	4	4	4	5	4
Identity of Letter	5	5	5	5	5	Identity of Letter	5	4	5	5	5
AVERAGE						AVERAGE					

Figure 5.3: Example of marking sheet design for jury.

The pre-existing knowledge of Devanagari script due to parental intervention as against the school grooming was found to be the cause of the failure of the Final Experiment. Thus, to obtain true results of the experiment, the experiment was repeated on the students of a school in the state of Karnataka. The results hence proved that the practice treatment of the specially extracted Devanagari primitives significantly affects the handwriting acquisition of the new learner as compared to other practices.

From the results of the experiment conducted to test the effect of the extracted Devanagari primitives (Chapter 4) we conclude the following:

Devising a system for manual extraction of primitives of letterforms for handwriting purposes is possible.

Primitive stroke practice significantly affects the handwriting acquisition of letterforms. A letterform comprises of basic strokes. But, here primitive means the scientifically extracted basic strokes that are unique in their visual appearance as well as in direction that they follow. Therefore, practice of such primitives guides the appropriate finger movement required for correct acquisition of letterform. Hence, practice of primitive strokes before complete letter is fundamentally an important stage.

The development from basic strokes to complete letter writing is a longitudinal process in a child's life. First script learned child is equipped with fundamental aspects for handwriting acquisition such as pencil grip and certain amount of directionality required to draw a stroke. Hence, child is equipped with the essential abilities which help in handwriting acquisition. Therefore, such a child becomes a suitable subject to test the effect of primitives on handwriting acquisition. Therefore, it is suggested to select subjects who are not exposed to the script one wishes to test.

Devanagari basic and compound stroke practice was found conducive for correct acquisition of Devanagari letterforms.

Thus we can generalize that ‘X’ basic strokes of ‘X’ script helps in acquisition of that ‘X’ script. Hence, the primitives of every script need to be extracted independently.

Children learning more than one different script simultaneously in early age are suggested to take combined basic stroke practice for more than first script/mother script.

5.2 Limitations of the study

The extracted primitives were tested on the school children within a stipulated time for practice. Therefore, the results only show the immediate effect on letterform writing acquisition. Handwriting acquisition as a whole is a longitudinal practice based process (1-2 years process in new learner’s life). For example, the process of handwriting acquisition covers entire schema from Letterform writing, word, sentence to achieve fluency in handwriting. This research is only limited to the fundamental stage in entire process of handwriting acquisition.

5.3 Contributions

Our conducted exercises and experiments identified the most fundamental fact that research into handwriting acquisition from morphological perspective will always remain script specific and hence cannot be standardised as the morphological aspect of every script is different. (*Ref. Chapter 2, Sections 2.1 to 2.7*)

We discovered that the manual method of extraction of primitives of letterform is essential for visual and movement similarity analysis of letterforms for handwriting. (*Ref. Chapter 3, Section 3.1*)

We found that unidirectional primitives are insufficient to give justice to graphical aspects of complex scripts. Hence, another level of Multi-directional compound primitives is essential especially in case of Devanagari. (*Ref. Chapter 3, Section 3.8*)

We developed the design for a practise sheet of basic strokes inevitable for the methodical conduct of a test. (*Ref. Chapter 4 Section 4.4.1 – 4.4.2, Section 4.2.2*)

Through the experiments conducted and results inferred, we discovered that the selection of subjects with unexposed background to a given script is appropriate to measure the effect on handwriting acquisition. Thus practice of appropriate basic stroke is found conducive in correct handwriting acquisition. (*Ref. Chapter 4, Sub-Section 4.6.4 to 4.6.9*) (*Ref. Chapter 4, Sub-Section 4.7.3 to 4.7.5*)

By identifying the stroke based factors of the hand written letterform, we designed and developed an evaluation system for measuring the levels of handwriting acquisition. (*Ref. Chapter 4*)

The results of Final Experiment conducted in Bangalore, Karnataka public school on the children who are not aware about any other script than Kannada proves that morphological script acquisition for handwriting purposes can be independently acquired without the need to learn the spoken language. (*Ref. Chapter 4, Section 4.7*)

5.4 Future Scope

In today's fast changing era of globalisation, it is expected that many countries are on the brink of becoming multi-lingual and henceforth multi-script. Therefore, we hope this study will help the designers of the forthcoming generations to conduct scientific enquiries for various scripts, which will empower the multi-script and morphologically diverse nature of Indian scripts. With this regard, we suggest the following future directions of research:

- Transferability of the method-
Using the manual extraction method used in chapter 4, one can extract primitives for other complex scripts as well.
- Digitisation of the extraction method-
Transforming the manual process into a digital process (manual inputs received on digital device) can help to conduct visual and movement similarity analysis on a larger scale which will lead to more precise extraction of primitives.
- Digital tool for measuring levels of letterform acquisition-

Manually conducted post-test inputs received on a digital device can be evaluated digitally by a programme designed with the help of evaluation factors.

Appendix

Appendix I

Dr. Bhagwat's Classification of Devanagari Letters and **our arguments are in column to extreme left:**
As sited in (Naik, 1971)

Dr. Bhagwat's Description	Devanagari	Roman	Our observation/argument
Table 46- Two groups according to simplicity or complexity.			
Table 46 – Point 4 A simple letter: One which usually consists of a single stroke and can be written without stoppage of motion.	उ र	<i>a c e</i> <i>m n o</i> <i>r s u</i>	Dr. B. is referring to 'script hand' and not a 'print hand' when comparing with Roman. As per his definition letter उ does not contain only straight stroke. No clue of what stage of handwriting he is referring to. Does he mean 'Simple' looking (for the reader?) or simple for writer? In any case then how letters like- त, व, प, ट, are not simple?
T.46- P.5- A Compound Letter: One which consists of more than one stroke involving loss of motion between two strokes.	ओ ख झ क्ष	None in English	When D.B. is stating here-" None in English" is he considering capital letters that are still used in everyday Roman handwriting? While doing lower case letter <i>t</i> pen lift take place and direction of hand goes in adverse (to the left).
Table 47- Seven groups according to motion, stroke and angles.			
T.47- P.6- Right Motion: That which takes the pen from left to right.	र	All English letters	While writing in Devanagari if stroke order ends with ' <i>shirorekha</i> ' head line, then DB's claim looks irrelevant, since headline of every letter starts from left and end in to right. Hence how one perceives stroke order while writing is an issue here. That also gives boost to our enquiry about why we should make a common decision of stroke order while learning Devanagari handwriting.
T.47- P.7- Left Motion: That which takes the pen from right to left.	उ ऊ ड	None in English	
T.47- P.8- A front stroke: That which has the inclination towards the right of the writer.	र	All English letters	While using terms like 'inclination' DB expect to state the 'inclination of the overall look of a letter form'. He is describing as an onlooker of a 'static form' and using these terms, like in typography the term that is generally used e.g. gravity of the letter form. DB is describing end form that take place after the act of writing. It clears us that he has not considered the ductus of handwritten letter, and only looking at the end result, the ultimate form. Therefore, we state, as handwriting is an 'Unfolding phenomena'.
T.47- P.9- A back stroke: That which has the inclination towards the left of the writer.	ऐ औ	None in English	
T.47- P.10- A right angle:	Every Balbodh letter has a right	None in English	(Once again) Is DB forming his opinion by referring to cursive hand, running hand or

Same as in Geometry	angle near the headline.		print hand? Is he taking capital letters from Roman handwriting in his account? Is he considering the letter 'Ra' while stating 'all Balbodhi' hand letters touching top line with right angel? In Balbodhi which form of letter Ra he refers to? this र or र the second form of 'Ra' is considered as more calligraphic Balbodhi hand and first one is more utilized by type designers.
T.47- P.11- An acute angle: Same as in Geometry	Non in Balbodhi.	<i>q</i> in English	If DB is describing acute angle same as geometry, then why not he is including letters like <i>p g y b d</i> from Roman script. That once again, creates confusion about what hand is he referring to while making the statement. What should be the ideal slant expected in running hand while handwriting, is still debatable issue among western scholars even in today's date, while DB stated this in the year 1961. In the research paper by Vi Supon, namely "Cursive writing: are its last days approaching?" He concludes by stating, "The aspects reviewed and discussed will not solve the difficulties of cursive writing" (Supon, Dec, 2009).
T.47- P.12- An obtuse angle: Same as in Geometry. Very inconvenient in writing.	ए ऐ	None in English	The movement in Balbodhi letter ए starts from left top and come down in obtuse angle but not difficult since movement of stroke is no other way round. It is natural for writer to complete the preceding letter to the right and hence only pen lift occurs upward to write letter ए as next letter.
Table 48- Six groups according to ending, flourishes, fenced etc.			
T.48- P.13- Front- ending letters: Those which have their endings in the direction of writing.	र	All English letters	What about Roman letters like lower case <i>b f j o s</i> ? These letters end in to adverse direction to Roman handwriting writing. Again here DB is not considering capital/upper case letters.
T.48- P.14- Back- ending letters: Those which have their loose ends in the opposite direction of writing.	ऊ ज ड थ ळ ल	None in English	All these <i>b f j o s</i> ends in to opposite direction to Roman writing direction. In running hand they need to make additional small loop/hook arrangement to go further for next letter in their writing direction.

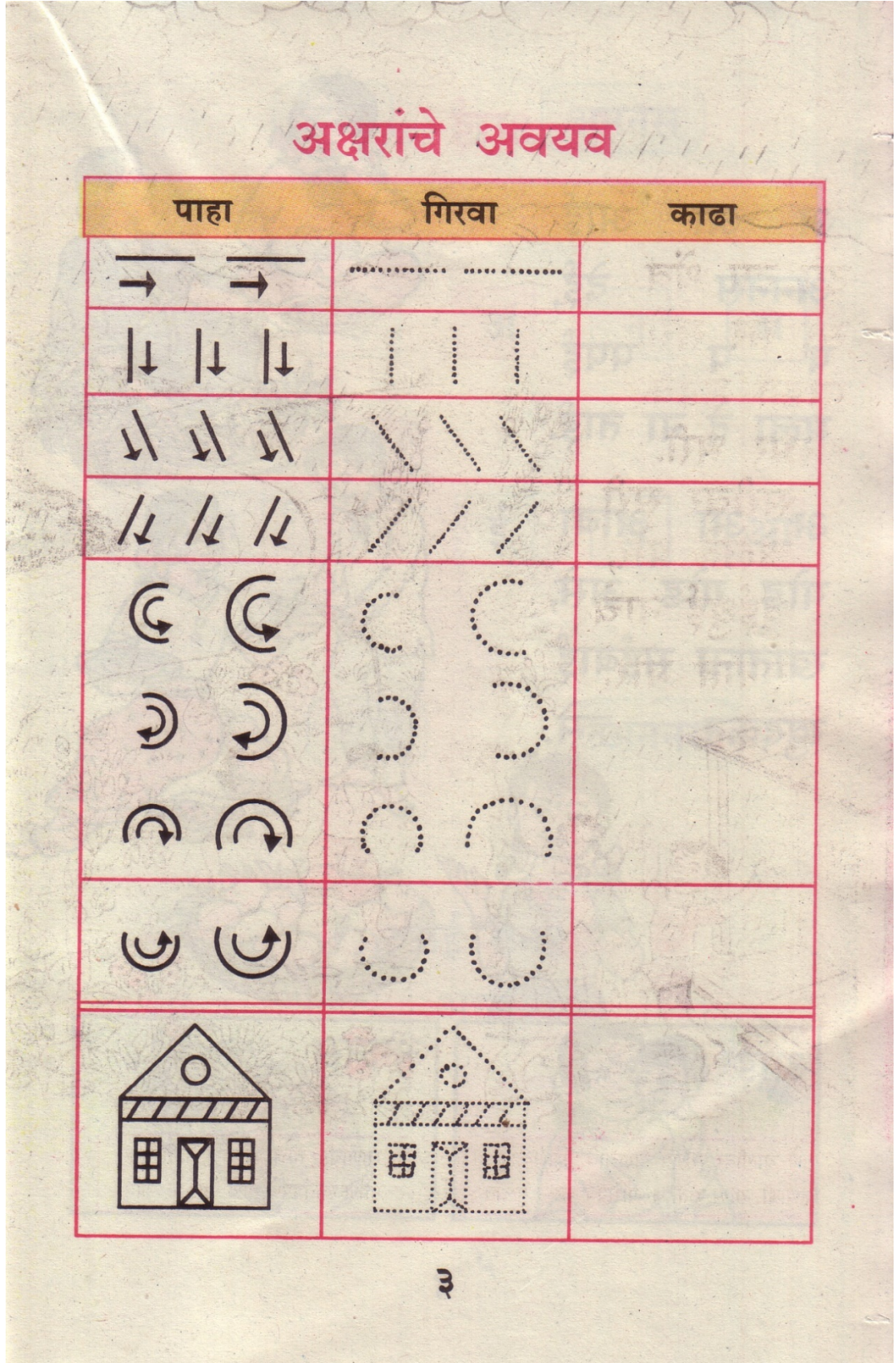
T.48- P.15- Fenced letters: Those whose movement in the direction of writing is literally barred by straight strokes.	ग च ण त ध न प भ स	None in English	DB's views about inscribed Devanagari refer only stone inscriptions (Naik, Typography of Devanagari-Volume Two , 1971) and interestingly how he doesn't consider the early manuscript era? Most of the traditional Jain manuscripts are the beautiful example of traditional Devanagari calligraphy in which lot of stylization is based on right hand vertical stroke. "In the graceful style of Devanagari, a rhythmic pattern is achieved by twisting the vertical stroke either once or twice resulting in a slightly complex yet very distinct calligraphic style" (Joshi, 1984) Hence DB's descriptive terms for Devanagari letter forms e.g. Fenced letters, literally barred appears personal and prejudice.
T.48- P.16- Turned feet letters: Those which have their vertical bars turned in the direction of writing by means of slurring hooks which come in automatically as a result of motion (Gujarati letters have such turned-feet which have contributed some flexibility and speed to Gujarati writing).	Non in Balbodhi.	All letters in English are turned feet when standing alone. When joined to other letters these turns become after-links	Turned feet letters, a fore-link and an after-link exists in Roman script due to its traditional calligraphic character to letter form. The important reason behind these less pen lift look, is basically provided by their traditional calligraphy tool. One doesn't find these in Roman Capitals found on Trojan Colum. We mean to argue here is this joint aspect of letter is a contribution of people's everyday writing. When script is used by many for regular purposes people added some features to core script form and hence made it faster from writers point of view. "All cursive writing, of course, is the result of the natural tendency of the hand to move in the direction of the writing, especially when writing rapidly" (Nesbitt, 1957) Earlier Devanagari and Gujarati users where using Modi script for regular correspondence. That has provided them great speed in writing aspect. The good mixture of Modi and Devanagari is still possible and seen in many peoples handwriting. Achut Palav termed this style aptly as ' <i>Drutanagari</i> ' (Palav, 1988). When one wants to acquire a speed in Devanagari by retaining readability one tends to join the letters automatically in flow. Once letters becomes handwriting habit, people have natural tendency to mold them for their convenience hence it is uncontrollable phenomena. Holding core form of script
T.48- P.17- A fore-link: A flourish of pen which in a running script connects the following letter to the preceding one.	Non in Balbodhi.	In the running script ever English letter has a fore-link	
T.48- P.18- An after-link: A flourish of pen which in a running script connects the preceding letter	Non in Balbodhi.	In the running script ever English letter has an after-link. Very often this makes a	

with the following one.		free bend with the fore-link of the following letter.	responsible is not justifiable. Therefore teaching 'script hand' first as against 'print hand' for Roman is still in debate and unsolved issue. Currently we don't have such problem. We only need to look at correct sequence of letter formation, implanted in child's early age.
Table- 49- Groups according to the parts of the letter design.			
T.49- P.19- Head-line: Line from which the letter starts in Balbodh.	Every letter in Balbodhi.	None in English	People have different solutions to deal with top line aspect of Devanagari. In mature stage of writing Devanagari people write the whole word first without top line and then add top line for the entire word.
T.49- P.20- A straight stroke: A straight line drawn at one stroke of pen in any direction.	(i) Central Bar as in- क फ (ii) Side bar as in- घ च थ (iii) Kana as ditched Bar as in- आ ग ण (iv) Connectives as in- अ स (v) Diacritics as in- औ प्र	None in English	Here DB is classifying Devanagari graphically from readers point of view, considering letter as a static form. While doing so he is not looking at Roman static form particularly 'print hand'.
T.49- P.21- A curve: A single roundish movement of pen on paper which is part of a "round" drawn by hand- not to be confused with geometrical curve which is necessarily part of an exact circle.	Many Balbodh letters have curves along with straight strokes and connectives.	Every English letter has a curve unaccompanied by any straight strokes or connectives.	DB is referring Roman letters as 'Ball and stick approach' (a well-known approach in teaching 'print hand' of Roman script). So far looks like DB is not considering 'Print Hand' but suddenly at this point he is referring 'Print Hand'. Hence he needs to first make reader clear about which hand he is referring while comparing with 'Balbodhi' the only hand for Devanagari. There is no scientific literature found on what is 'Balbodhi hand'. Except this term first used by Sant Ramdas in his section 'Lekhankriya'.
T.49- P.22- A fly- loop: An oblong slender loop which is both the result as well as the cause of motion in writing.	Non in Balbodh.	Every full line English letter has a fly-loop which may or may not be visible in what is called 'ascenders' and	Fly-loop in Roman is basically a requirement of a writer and not necessary of a reader. Comparing Devanagari Balbodhi (print hand) is hence unjustifiable in this regard.

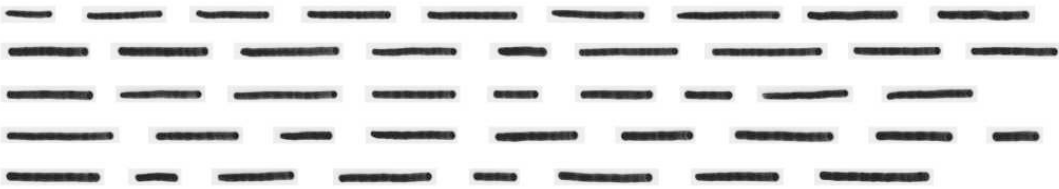
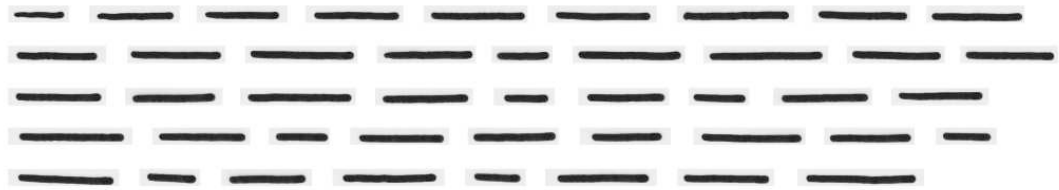
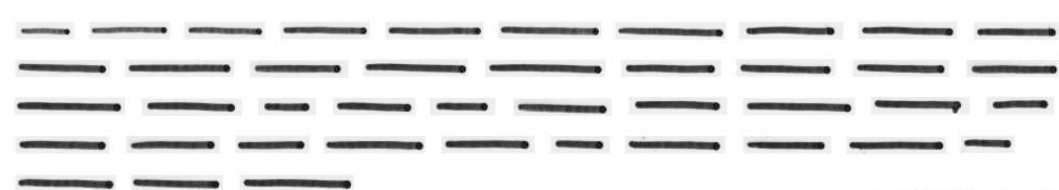
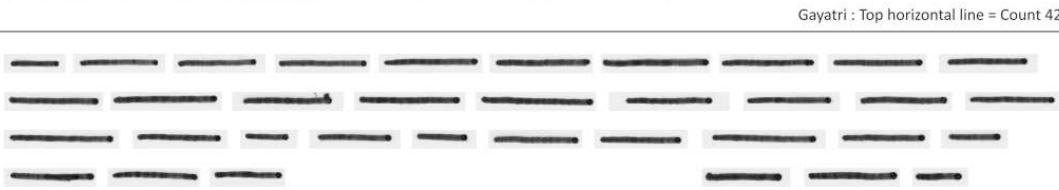
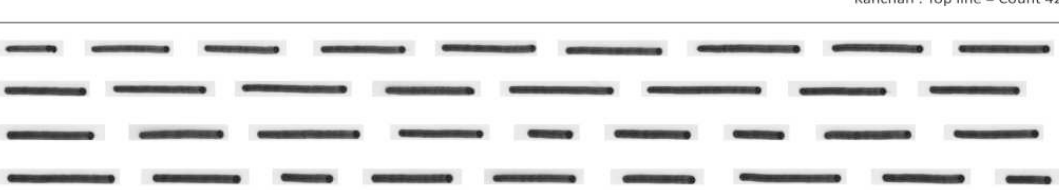
		'descends'.	
T.49- P.23- A circle: Flexible "rounds" drawn by hand on paper; not necessarily geometrical in shape.	(i) Small Circle: ग छ ढ ध न क्ष (ii) Big circle: क ख ठ ळ	<i>r s v w</i> <i>a d g o</i>	What kind of geometry DB is referring? Here it is unclear. While applying script to moveable type technology every script has undergone in geometricizing its core structure.
T.49- P.24- A fly- wheel: A small medial circle which is both the result and cause of quick motion in writing. This sometimes looks as a merged dot.	अ इ ख द श स र क्ष ज्ञ	<i>r s v w</i>	Is he referring 'Ganth' while using term like merged dot? The knot and loops are the important features of Devanagari script.
T.49- P.25- A letter- peg: A small vertical dash (or short bar) hanging from the head- line and supporting the main body of a letter.	इ ङ छ ट द ल श ह ळ	None in English	
T.49- P.26- A break: Sudden stopping of writing motion involving lifting of pen from paper. (It is therefore an unseen stroke).	Every Balbodh letter has necessarily a break at the head-line.	None in English	
T.49- P.27- A flexible: A straight stroke which becomes slightly curvish as a result of motion, taking away all the stiffness of straight lines as we find them in geometry.	Non in Balbodh.	All English ascenders and descenders are flexible.	
T.49- P.28- A stroke: Simple visible motion of pen on paper (straight or	Every letter consists of more than one stroke in Balbodh.	Some English letters consist of single stroke e.g. <i>a c e í</i>	

curvilinear) involving no angle or a change of direction.		<i>n o w v</i>	
T.49- P.29- A loop: A small graphic loop which requires no extra effort.	Non in Balbodh.	The English letter <i>e</i>	
T.49- P.30- (a) A merged dot; or (b) A merged circle: A graphic point attached to the beginning or end of a letter. The motion of a letter either starts or stops with it. Often it is individual writing mannerism.	ग छ ढ थ ध न भ र क्ष	<i>C</i> in English	
T.49- P.31- A running dot: A medical dot which acts as a fly- wheel.	द स श	<i>r s</i>	
T.49- P.32- A writing dagger: A straight stroke thrust through the body of letters without overspreading their normal size.	ब ष	None in English	
T.49- P.33- A dot: Same as in geometry. Easiest to write- (300 per minute)	अं अः ङ	<i>i j</i>	

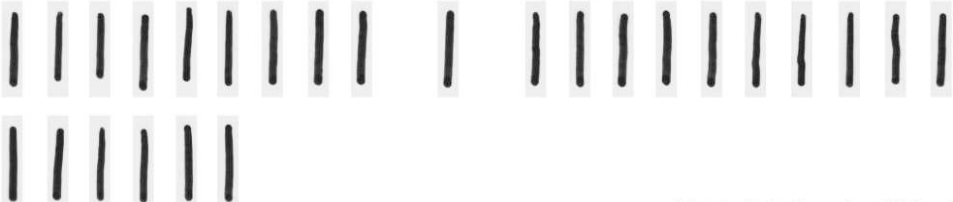
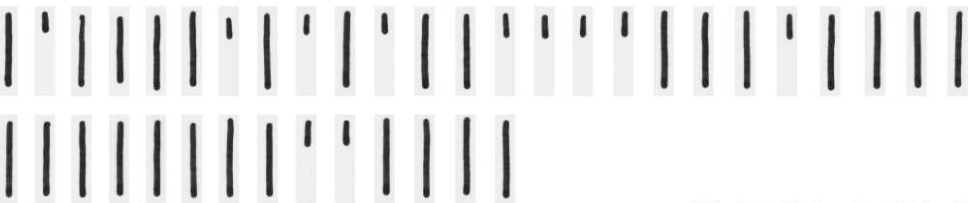
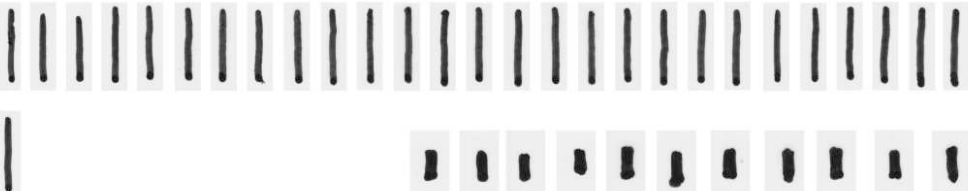
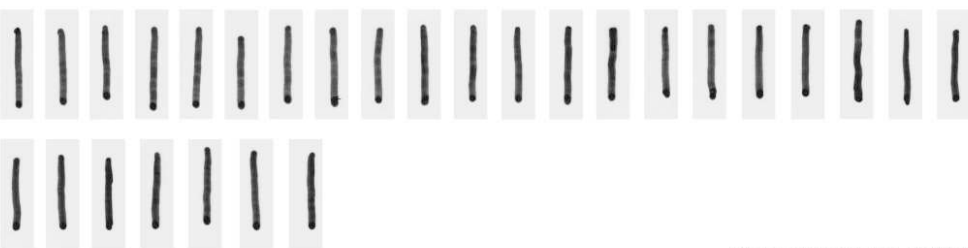
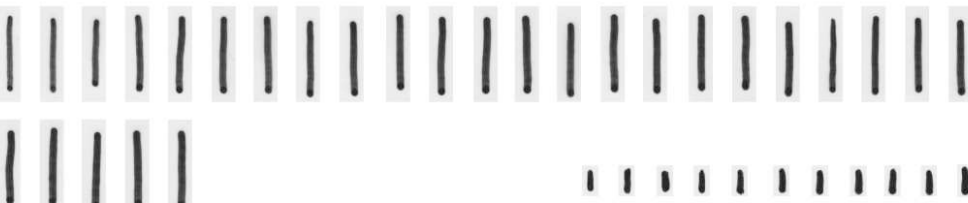
Appendix I-a



Appendix II

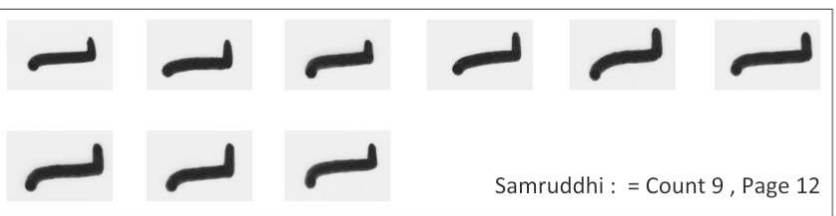
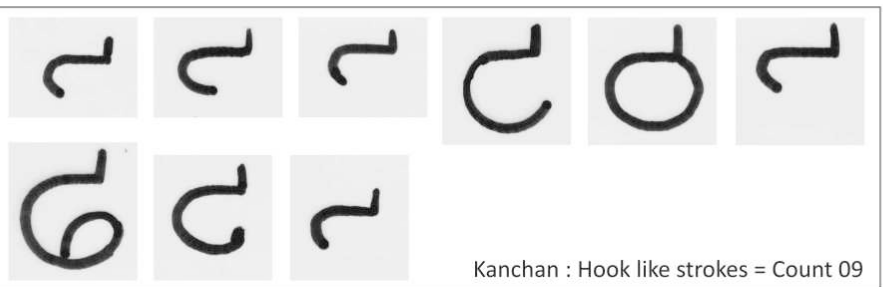
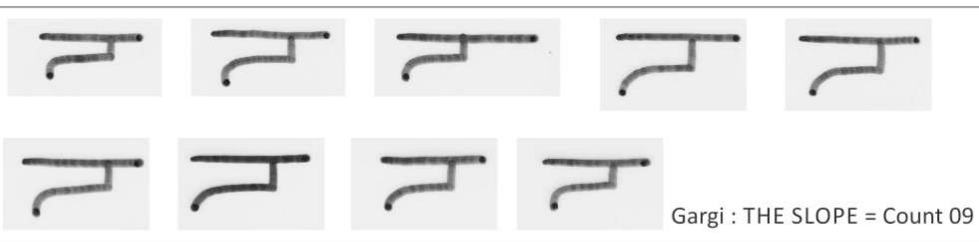
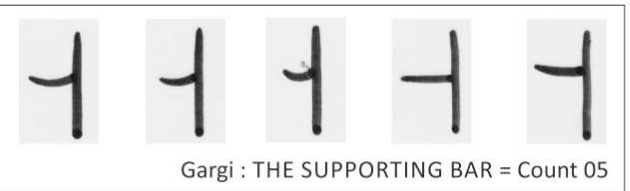
P-1	
	Ashutosh : Horizontal lines = Count 44 , Page 1
	Kabir : Horizontal Strokes = Count 44 , Page 2
	Gargi : THE FLAT = Count 42
	Gayatri : Top horizontal line = Count 42
	Kanchan : Top line = Count 42
	Samruddhi : Adavi Resha = Count 42 , Page 1

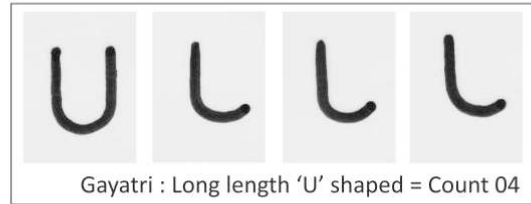
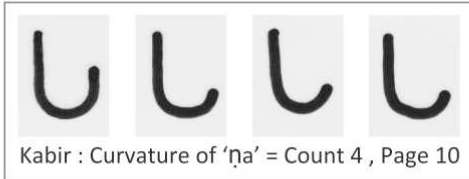
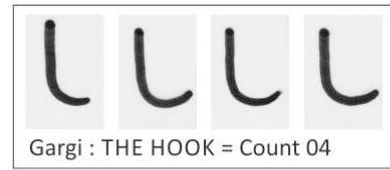
P-2

	
Ashutosh : Vertical lines = Count 28 , Page 2	
	
Kabir : Vertical Strokes = Count 39 , Page 1	
	
Gargi : THE VERTICAL BAR = Count 27	
	
Gayatri : Vertical line = Count 28	Gayatri : small vertical line = Count 11
	
Kanchan : Full vertical bar = Count 28	
	
Samruddhi : Ubhi Resha = Count 28 , Page 2	Samruddhi : Choti Ubhi Resha = Count 11 , Page 9

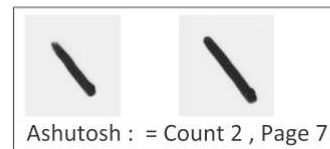


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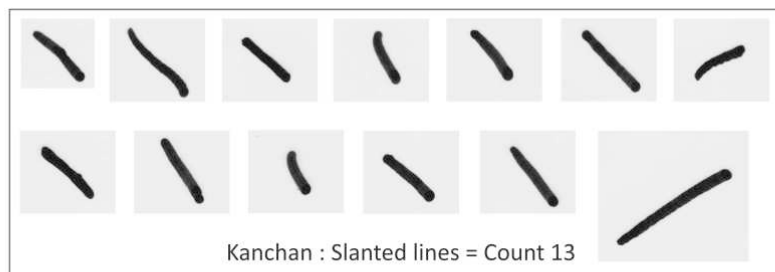


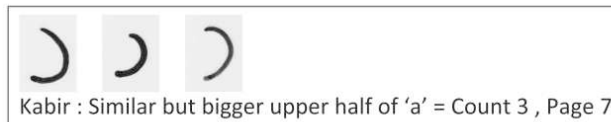
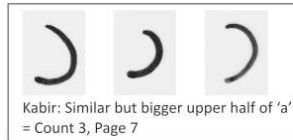


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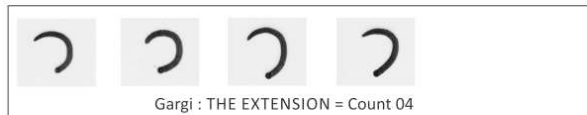


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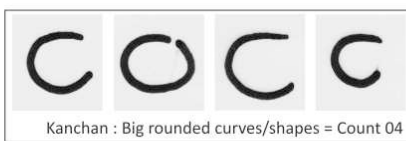
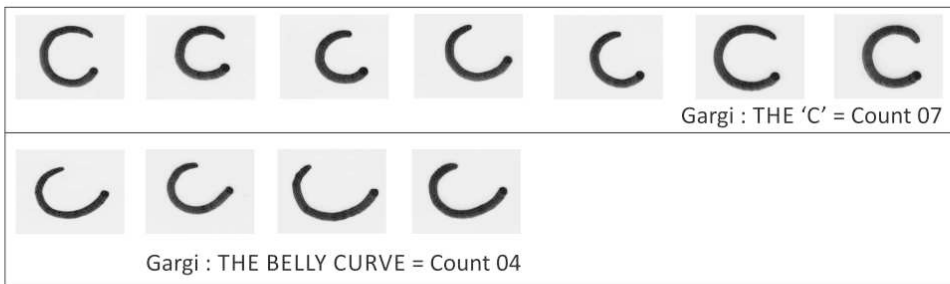
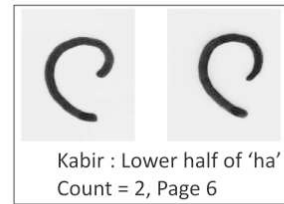
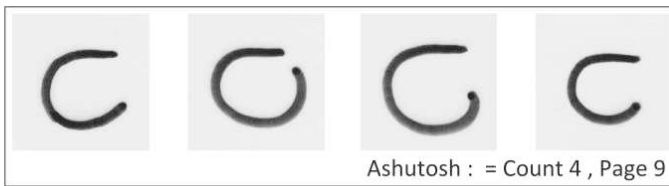


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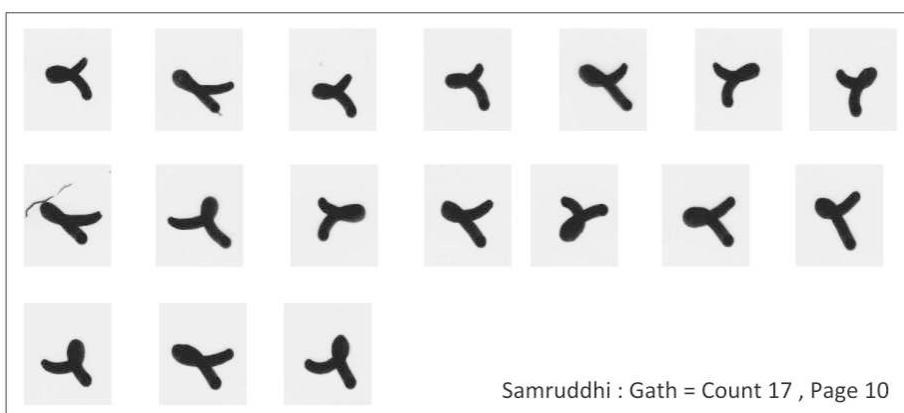
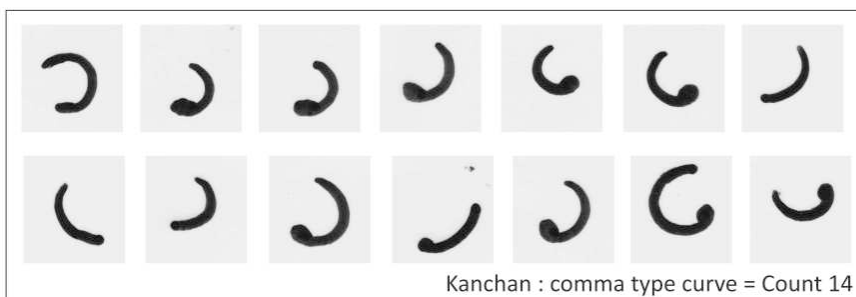
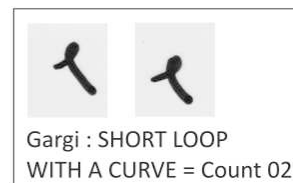
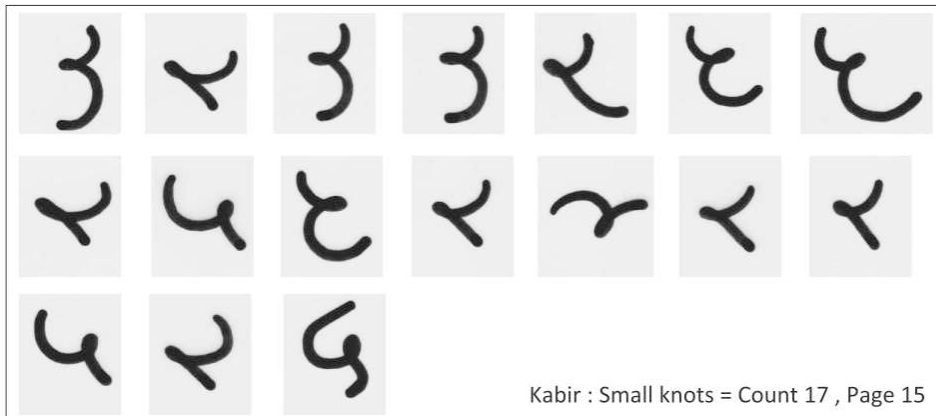


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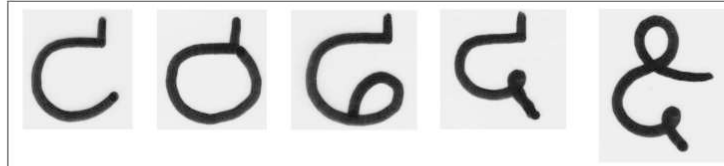


P-8





P-9



Gayatri : anti - clockwise round long stroke = Count 05

P-10



Ashutosh : = Count 3 , Page 13

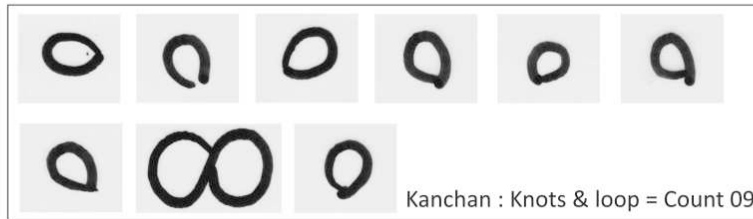


Gargi : LOOP AT THE START = Count 02



Gargi : THE KNOT = Count 04

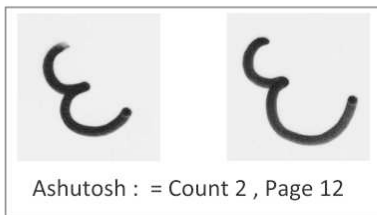
P-11



Kanchan : Knots & loop = Count 09

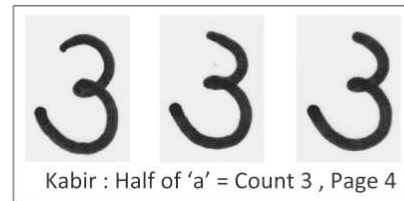


Samruddhi : Ek anka = Count 6 , Page 6

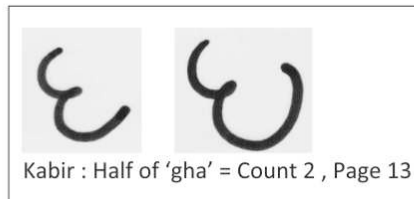


Ashutosh : = Count 2 , Page 12

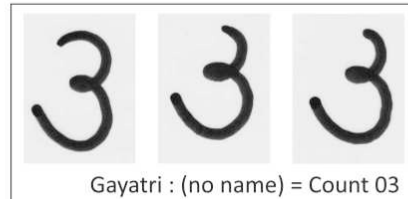
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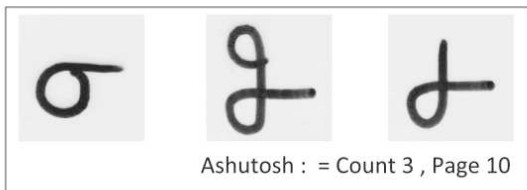
Kabir : Half of 'a' = Count 3 , Page 4



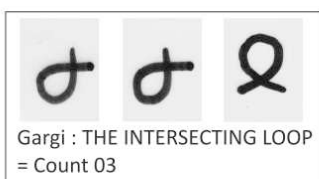
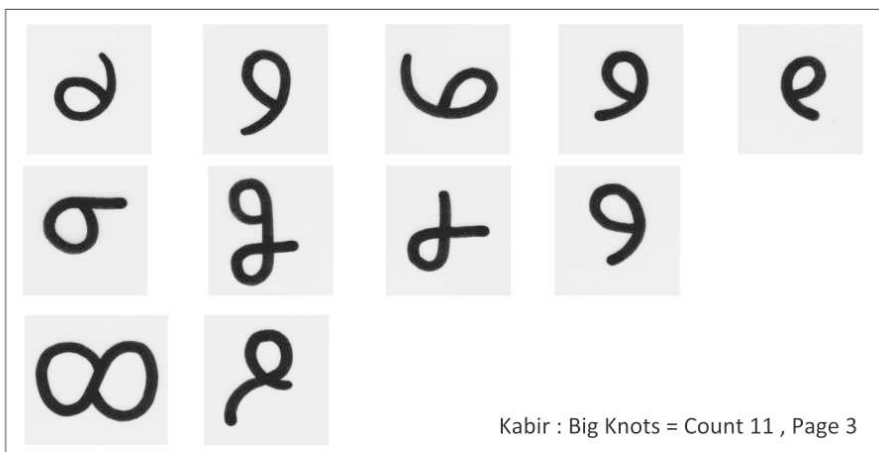
Kabir : Half of 'gha' = Count 2 , Page 13

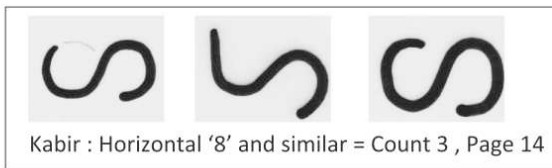
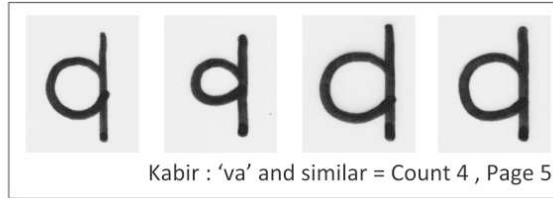


Gayatri : (no name) = Count 03

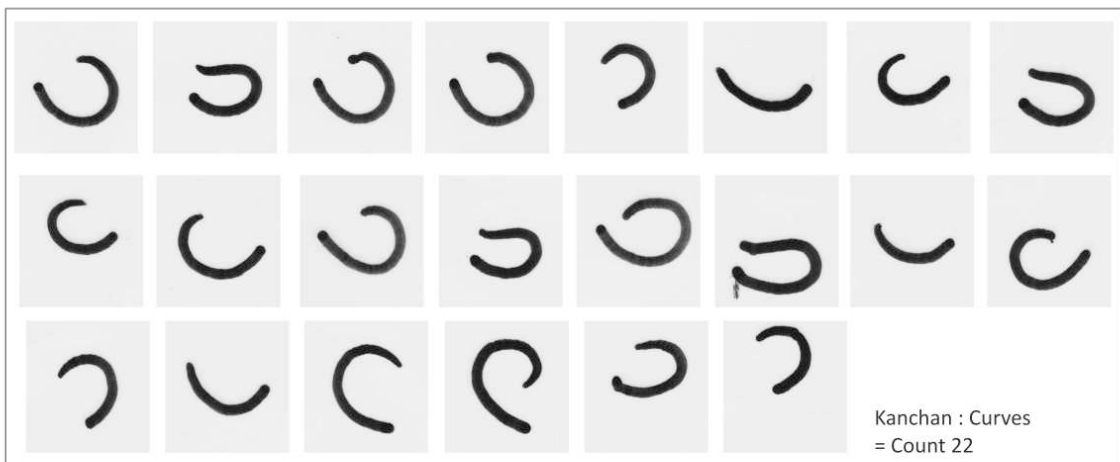
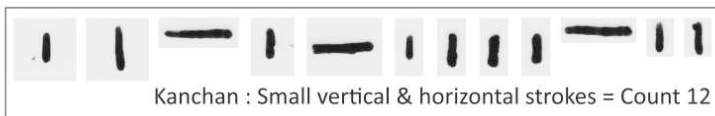
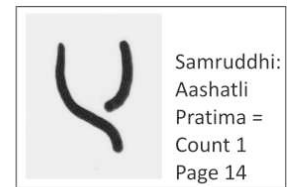
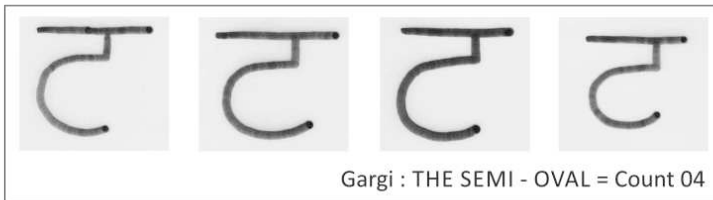


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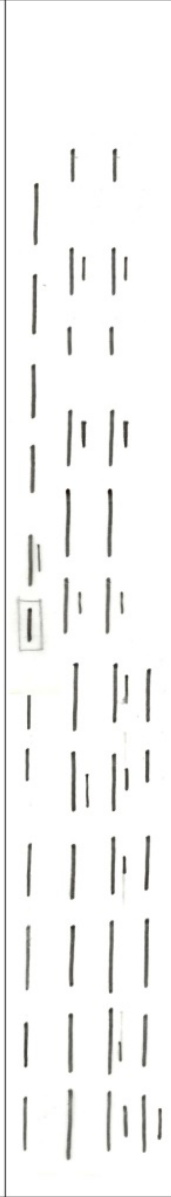
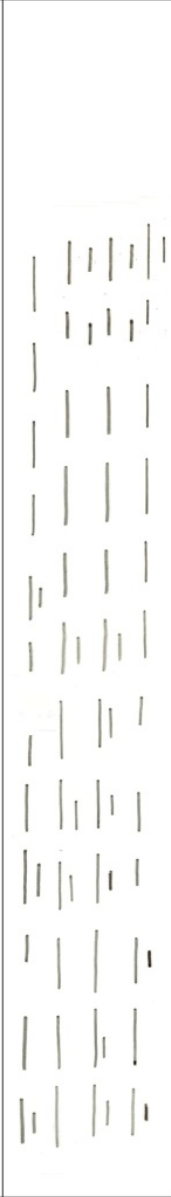
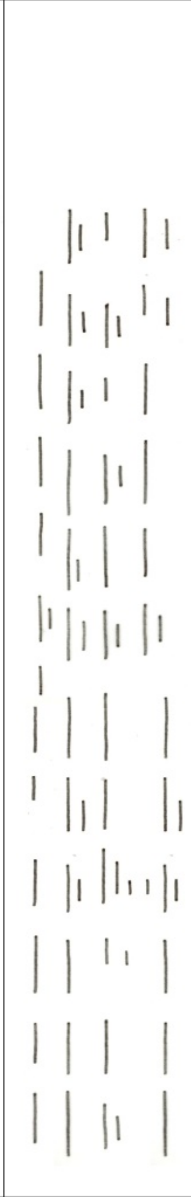
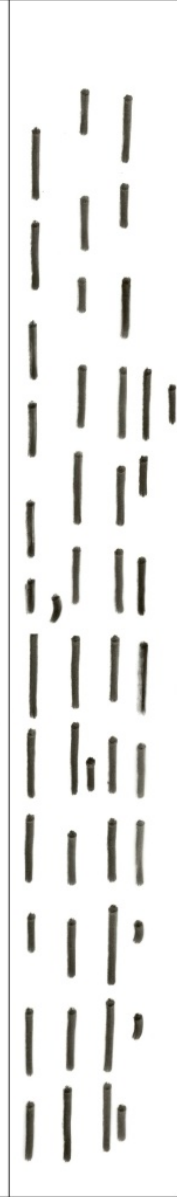




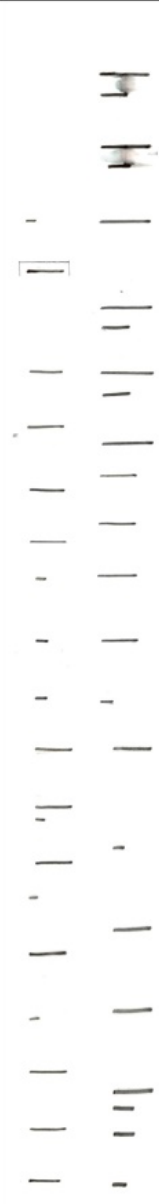
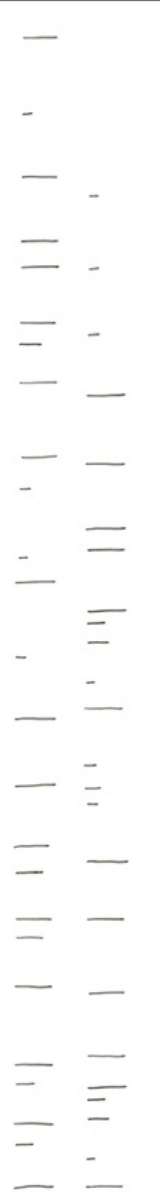
P-14



Experts Extracted Strokes

	45	
	58	
	58	
	62	
	48	

mi, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

	28	
	45	
	46	
	48	
	38	

ii, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

	1	10
		
	2	9
		
	3	13
		
	1	14
		
	2	11
		

ii, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

Kind of handwritten Stroke Clockwise curve	
17	
22	
22	
20	
13	

ni, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

6	
7	
25	
28	
16	

ii, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

5 005 5 5 5	6	5 5	2

i, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

Curve to straight line Clock or Anti-clock		Straight to curve line any direction	
	2		15

ii, D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

	 	2		
			   	4

D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

Anti-clockwise knot

Clockwise knot



11

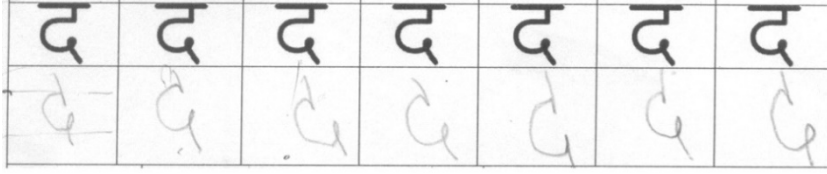


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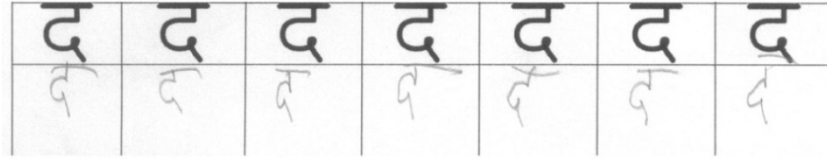
D.2 Pradnya Naik, D.3 Pallavi Karambelkar, D.3 Snehal Patil, D.5 Nanki Nath

Appendix III

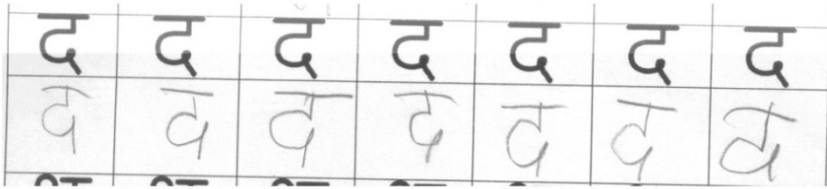
Basic_Stroke_Group



Apurva_Basic_Stroke_Group_S1



Viraj_Basic_Stroke_Group_S2

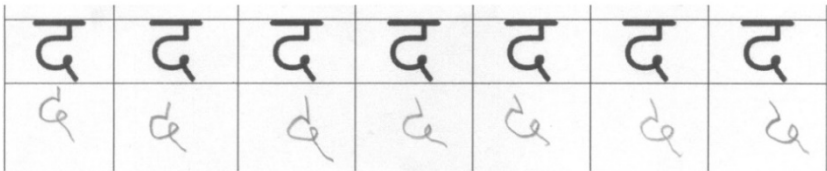


Kalyani_Basic_Stroke_Group_S3

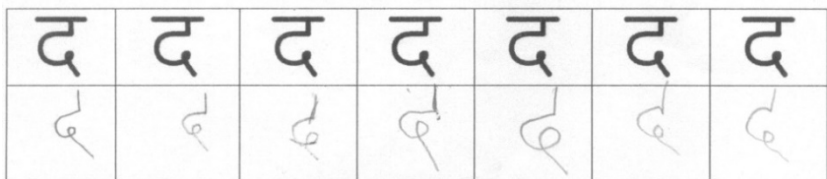
Dev_Stroke_Group



Sahil_Dev_Stroke_Group_S1

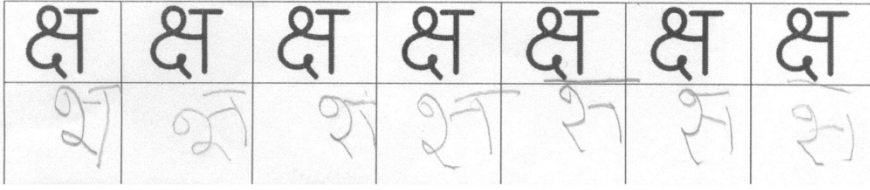


Saishree_Dev_Stroke_Group_S2

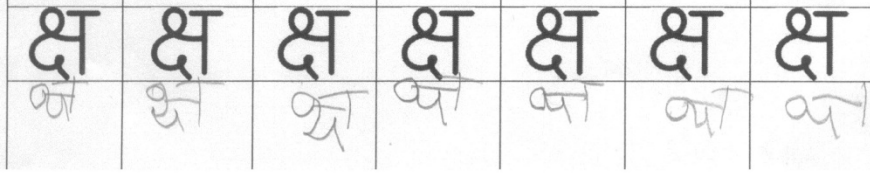


Rohit_Dev_Stroke_Group_S3

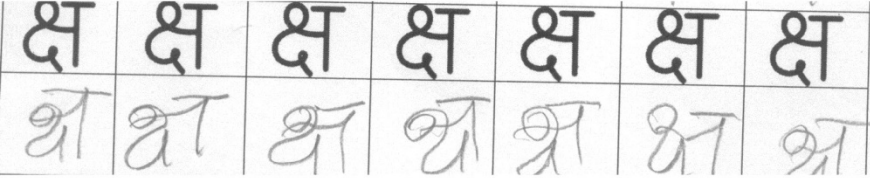
Basic_Stroke_Group



Apurva_Basic_Stroke_Group_S1



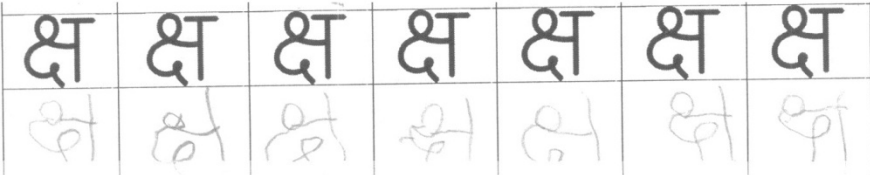
Viraj_Basic_Stroke_Group_S2



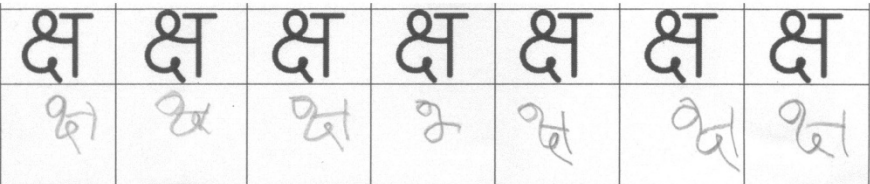
Kalyani_Basic_Stroke_Group_S3



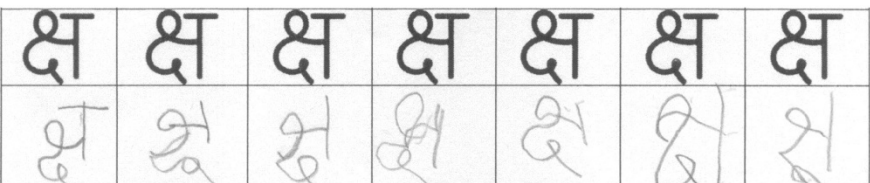
Dev_Stroke_Group



Sahil_Dev_Stroke_Group_S1

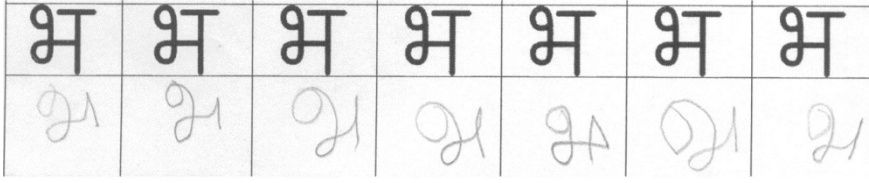


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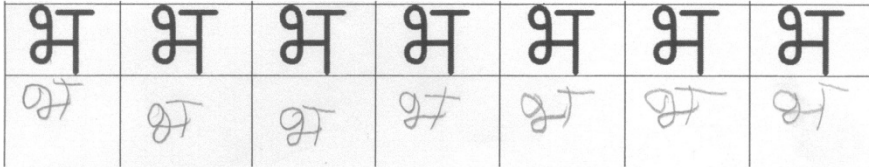


Rohit_Dev_Stroke_Group_S3

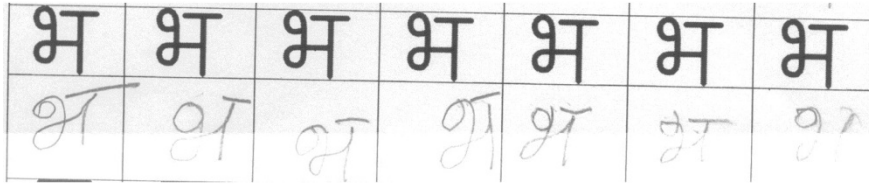
Basic_Stroke_Group



Apurva_Basic_Stroke_Group_S1

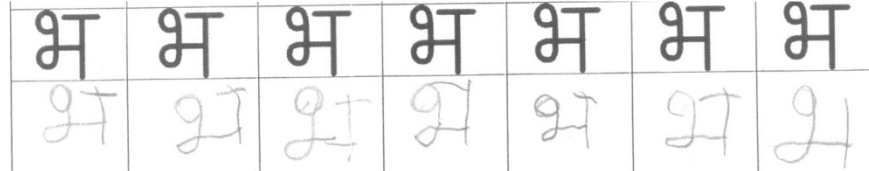


Viraj_Basic_Stroke_Group_S2

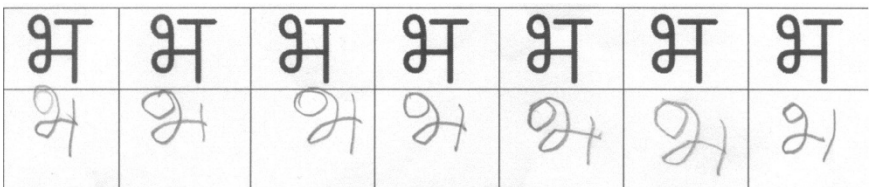


Kalyani_Basic_Stroke_Group_S3

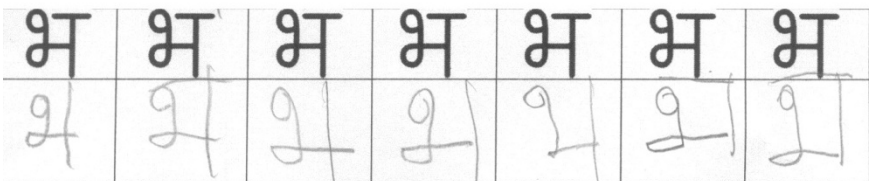
Dev_Stroke_Group



Sahil_Dev_Stroke_Group_S1



Saishree_Dev_Stroke_Group_S2



Rohit_Dev_Stroke_Group_S3

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DATE	05/11/2012		TIME: 01.45 Noon		TEST CODE: BT	

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د	د	د	د	د	د	د
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ث	ث	ث	ث	ث	ث	ث
NAME				CODE		
D.O.B.				GENDER	M / F	
SCHOOL	Aryan Education Societies' High School. (Sr. KG. class)					
DATE	/11/2012		TIME: 01.45 Noon		TEST CODE:	

Appendix IV

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List of Presentation & Publications

Peer reviewed article published in international journals:

1) International Graphonomics Society, 16th IGS Conference: 10-13 Jun. 2013 Naraa, Japan (IGS2013)

Published in online proceeding.

2) International Conference on Research into Design, ICoRD-2014

Proceedings published in book form by- Springer India.

3) The Learner, Common Ground Publishing, 2015-16

The International Journal of Literacies - ISSN: 2327-0136 (print), 2327-266X (online)

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International Conference presentations:

1) International Conference of Typography and Visual Communication, ICTVC-2010 University of Nicosia, Cyprus

2) Typography Day 2012, at Indian Institute of Technology, Industrial Design Centre, Investigating Handwriting practice manuals in current scenario.

Workshops: National and International level:

1) Association Typographique Internationale, Atypi-Dublin 2010

2) National Institute of Design, R & D Campus, Bangalore, India 2012

3) Department of Design, IIT Hyderabad, India 2016

4) Typography Day, Organised by IDC, IIT, Aksharaya and host institutions:

4.1) Industrial Design Center, IIT, Powai, Mumbai, India 2008

4.2) Sir J. J. Institute of Applied Art, Mumbai, India 2010

- 4.3) National Institute of Design, Ahmedabad, India 2011
- 4.4) Industrial Design Center, IIT, Powai, Mumbai, India 2012
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- 4.6) Symbiosis Institute of Design, Pune, India 2014
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Invited as an expert by- ALBA University, Beirut, Lebanon 2015

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Other published writing:

‘Vishwakosh’- Marathi knowledge encyclopedia, ‘Sulekhan’ historical research based article published about Indian Calligraphy focusing more on Devanagari calligraphy. 2012.

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Mrs. Preeti Karande Rajwade

Ms. Pradnya Naik

Mr. Kalpesh Gosavi

Faculty / Formal:

Prof. G. G. Waghmare- Dean, SJJIAA

Prof. G. G. Ray- HOD, IDC, IITB.

Prof. Nina Sabnani, IDC, IITB.

Dr. Girish Dalvi IDC, IITB

Prof. Anirudh Joshi IDC, IITB

Prof. Shrikumar IDC, IITB

Administrative staff IDC, IIT

Dr. Baraal R&D NID, Bangalore

Mr. Manoj Nilkanthan, Infosys,
Bangalore

Mr. Girish Patke- RMVK

Mr. Sushant Devlekar- RMVK

Dr. A. D. Sawant, Ex-Vice Chancellor,
Mumbai University

Dr. Sanjay Ranade, Dept. of
Journalism and Mass Communication,
University of Mumbai.

Prof. Rajiv Mishra, Directorate of Art,
Principal of Sir J. J. School of
Architecture.

Mr. Mustansir Dalvi

Dr. Ajanta Poovaiah

Experts:

Dr. Dinesh Katre- CDAC

Dr. Baijool Desai

Dr. Shreenand Bapat

Dr. Ramesh Panse

Dr. Sonali Nag

Prof. Milind Malshe

Mr. Ashok Shahane

Mr. Mukund Gokhale

Dr. Ajanta Sen Poovaiah

Prof. Mary C. Dyson, University of
Reading, UK

Prof. Gerry Leonidas, University of
Reading, UK

Prof. Shantaram Pawar

Friends from IDC:

Prof. Nilkanthan P. K.

Prof. Roopa Agarwal

Dr. Sachine Datta

Dr. Sushmita Sharma

Prof. Udaykumar D.

Prof. Prasad Bokil

Dr. Rajendra Patsute

Dr. Pramod Khambete

Dr. Kaumudi Patil

Mr. Abhishekh Shrivastav

Mrs. Anisha Malhotra

Mr. Aakash

Mr. Ravishankar

Friends:

Ms Radha Mehta

Ms. Sumanthri Samarawickrama, Sri
Lanka

Mr. Pathum Egodawatta, Sri Lanka

Mr. Adesh Navkudkar

Mr. Ravi Joshi

Ms. Dnyanada Deshpande

Mr. Saurabh Bondre

Mrs. Malvika (Anagha's friend)

Mrs. Archana Kshirsagar

Helped in experiments and survey projects:

Group of 5 children (1st mini P)

Group of 5 American students from
Pune

Class of 100 Students from JJIAA

Team of (20+) students assistance
from JJIAA

Team of (20+) students assistance
from NID

Mr. Shubhanand Jog

Mrs. Meghana Samant P.

Dr. Desai- Raja Shivaji- High school

Mrs. Shushama Joshi- Aryan High
school

Ms. Nanki Nath IDC

Mr. Yogesh Jahagirdar

Ms. Pradnya Naik

Ms. Shubhangi Jadhav

Mr. Kalpesh Gosavi

Mrs. Vanarase

Mr. Babu Udupi

Mr. Chandramohan Kulkarni

Mr. Sham Deshpande

Mr. Jamdade (Pune)

Mr. Sujit Patwardhan

American students from Ferguson
College, Pune

Student Associates:

Mr. Kailash Malviya

Ms. Manali Rangnekar

Ms. Gurpreet Kaur

Mr. Makarand Narkar

Language and proof reading:

Mrs. Lavanya Varadrajan

Mrs. Noopur Datye

Mr. Salil Badodekar

Mrs. Malvika Gadhiyar

Libraries and Institutions:

IDC and IIT central library

Sir J. J. Institute of Applied Art,
Mumbai

Directorate of Art, Maharashtra State

Department of Higher & Technical
Education, Mumbai, Maharashtra
State

Department of languages Government
of Maharashtra State

Department of General Administration
Maharashtra State

Government Printing Press, Mumbai,
Maharashtra State

.....

Asiatic Society Library, Mumbai

Bal-Bhavan, Mumbai

Rajya Marathi VikasSanstha, Mumbai

.....

Gram Mangal, Pune

Anaath Vidyarthi Gruha, Pune

Chitra Shalaa Press, Pune

Bhandarkar Research Institute, Pune

Ferguson College, Pune

Bal-Bharti, Pathya Pustak

Mahamandal, Pune

Department of Design, IIT, Guwahati,
Assam

National Institute of Design,
Ahmedabad

R&D, National Institute of Design,
Bangalore

Central Institute of Languages, Mysore

University of Reading, UK

Pratham, Sarva Shiksha Abhiyaan

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