SINHALA TYPEFACE FEATURES TO OPTIMIZE READABILITY FOR SMALL SCALE DIGITAL DEVICE SCREENS

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DECLARATION

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ABSTRACT

Keywords: Sinhala Typography, Legibility, Similar Letter Misidentification, Small Screen Digital Devices, Sinhala Digital Fonts

The widespread use of digital devices for reading and communication has highlighted the need for optimized fonts for small-scale digital screens. This need is particularly important for languages with complex scripts like Sinhala, which require specific features to ensure readability. Unfortunately, the lack of digitally optimized Sinhala fonts is a major issue in the Sinhala typographic industry, prompting the need for research in this area. This thesis aims to identify the specific features of Sinhala typefaces that optimize readability on small-scale digital devices. The study has two objectives: first, to identify the role of general anatomical features of a script in designing a font for a particular purpose, and second, to identify the anatomical features of Sinhala typefaces that contribute to optimizing legibility on small-scale digital device screens.

The thesis discusses the challenges posed by small digital screens and the importance of legibility, as well as the research gap in Sinhala fonts designed to optimize legibility on small digital screens. A visual experiment was conducted to identify the most appropriate Sinhala font for the research based on legibility, and Noto Sans Sinhala was selected. The experiment identified the anatomical features that contribute to letter misidentification, and a visual survey was conducted on the most commonly misidentified letters in the selected sample font. The purpose of this experiment was to identify the impact of legibility on Noto Sans Sinhala through changes to its anatomical features.

The thesis discusses the differences between the Distinct Visual Features and the anatomical structure in Sinhala letters, how the legibility of a font is directly affected by anatomical changes to their Distinct Visual features through similar letter misidentification, and the anatomic features that need to be considered when designing a Sinhala font centered around increasing legibility for small digital screens.

The practical implications of this research are significant for designers seeking to optimize legibility and reduce similar letter misidentification in Sinhala fonts on small-scale digital device screens. By manipulating the visual parameters of each anatomical feature, designers can make specific changes to the DV features of letters and improve the legibility of Sinhala fonts on digital platforms. This research contributes to the field of Sinhala typography and legibility on digital screens by providing a deeper understanding of the specific features that impact legibility and similar letter misidentification, enabling designers to create more effective and legible Sinhala fonts for digital devices, improving the user experience and enhancing the communication of messages in Sinhala.

Dedicated to my pillars in life,
my parents, my wife and
my inspiration.

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LIST OF RESEARCH PUBLICATIONS

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CHAPTER 01: INTRODUCTION

In recent times, with the advent of technology, digital devices have become an integral part of our daily lives. Mobile phones, tablets, watches, and laptops have become ubiquitous, and we often find ourselves reading content on their small screens. However, displaying Sinhala fonts in small digital displays can become problematic due to their anatomical features. The lack of literature specific to Sinhala scripts in the context of digital screens further exacerbates this issue.

This research aims to identify the anatomical features of Sinhala typefaces that contribute to optimizing the legibility of small-scale digital device screens. The study focuses on body fonts only and aims to establish the role of general anatomical features of a script that contribute to designing a font for a purpose, in this case, legibility. The research methodology involves a review of the digital history of Sinhala fonts, typographic theories of Latin fonts related to legibility, and an experiment with the basic anatomical features of Sinhala fonts and their contribution to legibility.

This chapter provides an introduction to the overall research and highlights the problem statement. It also discusses the scope and aim of the research, outlining the research questions and objectives. Additionally, the methodology section details the research design and the steps taken to achieve the research objectives. Finally, the chapter concludes by providing an overview of the organization of the remaining chapters.

1.1 Background and Context

The widespread use of digital devices such as smartphones, tablets, and laptops has transformed the way we consume information. These devices have become an integral part of our lives, and we heavily rely on them for communication, entertainment, and work-related tasks. As a result, the demand for easily readable digital content has significantly increased in recent years.

One of the primary factors that influence the readability of digital content is the typeface used. Typeface design is a critical aspect of typography and can have a significant impact on the user's reading experience. Sinhala is a script used to write the Sinhalese language, which is the official language of Sri Lanka. Sinhala script has unique features compared to other scripts, which make it challenging to design typefaces that are easily readable on small-scale digital devices.

Several studies have focused on optimizing typeface design for readability on digital devices. But those studies focused mainly around investigating the anatomy of Latin fonts. However, there is a lack of research on Sinhala typeface design for small-scale digital devices and digital optimization.. This gap in knowledge is particularly relevant since Sri Lanka is one of the fastest-growing digital markets globally, and the majority of the population uses smartphones to access digital content. Despite the increasing demand for digital content in Sinhala, there is a lack of literature on Sinhala scripts' legibility in the context of digital screens. This gap in knowledge makes it challenging to develop effective design strategies for optimizing the legibility of Sinhala typefaces on small digital displays.

In the context of digital displays, using fonts designed primarily for printing purposes is not optimal, as the design parameters for printed materials and digital displays differ significantly. Digital displays require fonts that are optimized for screen resolutions, legibility, and other factors unique to digital media. Sinhala script presents specific challenges for designers creating typefaces for digital displays due to its anatomical features. Sinhala letters are composed mainly of circular strokes, making them more challenging to render accurately on digital screens, which typically rely on straight lines and sharp angles.

Applying anatomical analysis methods used for Latin typefaces to Sinhala letters is also not accurate. Sinhala letters' anatomy differs significantly from Latin letters, and analyzing Sinhala letters in the same way as Latin letters may not yield accurate results. The reference lines used in Sinhala letters, such as baseline and x-height, are also different from those used in Latin letters. Understanding these differences is crucial for developing effective design strategies for optimizing the legibility of Sinhala typefaces on small digital displays.

Thus, this study aims to investigate the features of Sinhala typefaces that optimize legibility for small-scale digital devices. The study will explore various aspects of Sinhala script, including stroke weight, x-height, contrast, and letter-spacing, among others, to identify the optimal combination of features that enhance the readability of Sinhala typefaces on small-scale digital devices.

This research is expected to contribute to the field of typography and digital content design by providing insights into the design of Sinhala typefaces for small-scale digital devices. The findings of this study can also inform the development of Sinhala typefaces that are better suited to the needs of Sri Lankan users who rely heavily on digital devices for accessing information.

1.2 Scope of the study

This study focuses on the design of body fonts for Sinhala script optimized for small digital display screens. The study concentrates on the anatomical features of the letters to identify design strategies that enhance legibility on digital screens. The scope of the study is limited to digital fonts that are widely used in the contemporary context.

The study's focus is on small-scale digital display screens, such as mobile devices, tablets, watches, and laptops, as these devices are the primary means of accessing digital content in Sri Lanka. By focusing on small screens, this study aims to develop design strategies that enhance legibility on screens with limited display real estate.

The study draws on various information sources, including books, journals, research papers, and interviews. Some of the methodologies used in the study have been adapted to suit the unique anatomy of the Sinhala script. By exploring the anatomical features of Sinhala letters, this study aims to provide insights into the design of Sinhala typefaces that are optimized for small digital display screens.

1.3 Problems identified

a) Lack of a digitally optimized Sinhala font is a problem in the Sinhala typographic industry.

b) The inability to apply typographic theories derived for Latin fonts into designing Sinhala fonts due to its anatomical differences

c) Identifying the distinct anatomical features that contribute to the identification of a specific letter in both Latin and Sinhala fonts.

d) Understanding how changes to distinct anatomical features can improve or degrade the legibility of a font is a research problem.

1.4 Aim and objectives

The aim of this research is to identify the anatomical features of Sinhala typefaces that contribute to optimizing legibility on small-scale digital device screens.

The aim of this research can be further divided into two sections. Firstly, the research aims to identify the role of general anatomical features of a script that contribute to designing a font for a specific purpose, in this case, legibility on small-scale digital device screens. This will be done by reviewing existing literature on typography, legibility, and digital content design to understand the key design factors that contribute to legibility on digital screens.

Secondly, the research aims to identify the specific anatomical features of Sinhala typefaces that contribute to optimizing legibility on small-scale digital device screens. By analyzing various design parameters unique to Sinhala script such as stroke weight, x-height, contrast, letter-spacing, and other design factors, the research aims to identify the optimal combination of features that enhance legibility on digital screens.

These two factors of the aim of the research can be described as 2 objectives;

i. Identify the role of anatomical features of a script which contribute to designing a font for a purpose (in this case legibility)

Ii. Identify the anatomical features of Sinhala typefaces that contribute to optimizing legibility of small-scale digital device screens

By identifying the anatomical features that contribute to legibility, this research aims to provide insights into the design of Sinhala typefaces that are optimized for small-scale digital device screens. The research findings will contribute to the field of typography and digital content design, particularly for Sinhala script, by providing designers with evidence-based design strategies to enhance legibility on digital screens.

The ultimate goal of this research is to improve the user experience of digital content in Sinhala by creating typefaces that are better suited to the unique features of small-scale digital display screens. The study's findings can be applied to the development of typefaces for various digital media such as mobile applications, websites, and e-books, thereby contributing to the overall improvement of digital content accessibility in Sinhala.

1.5 Methodology

This research will employ a mixed-method approach to achieve its objectives. The methodology will consist of a literature review, an analysis of existing fonts in Sinhala digital typography, and experimentation to identify the ideal digital font for small-scale digital device screens.

The first step of the methodology will be a review of the digital history of Sinhala fonts. This will be followed by an investigation into the current state of Sinhala digital typography and an analysis of the anatomical features of Sinhala typefaces. The aim of this analysis is to establish that there has not been enough research done into the subject of the anatomy of digital Sinhala type and to identify the basic anatomical features of Sinhala fonts.

To investigate the typographic theories of Latin fonts that relate to legibility, a literature review will be conducted. This review will focus on theories that can be applied to Sinhala script and digital content design.

The next step will involve experimentation with the basic anatomical features of Sinhala fonts to determine their contribution to legibility. This will be done by conducting experiments on Noto

Sans Sinhala, a widely used digital font, and manipulating its distinct visual features to identify their effect on legibility.

To establish ranges and patterns on these distinct visual features, the experiments will include testing for similar letter misidentification and distinct visual feature identification. These tests will help in deriving the ideal digital font that could be used in small digital devices while maintaining high legibility.

The methodology will also involve an analysis of existing fonts in Sinhala digital typography along with a brief analysis of their contextual and anatomical features. This analysis will help in identifying the existing font types that are better suited for small-scale digital device screens.

The main limiting factor for legibility in the digital context, especially in screens, is the size of the letter. Similar letter misidentification is the main key feature that can be used to measure legibility in a small scale font on the screen. To experiment with this, similar letter misidentification tests will be conducted on Noto Sans Sinhala.

Finally, the methodology will involve experimenting on how changes and distortions to each distinct visual feature of Noto Sans Sinhala affect the legibility of the font. These experiments will focus on establishing how changes to distinct visual features of Noto Sans Sinhala affected the legibility of the font and will help in deriving the ideal digital font for small-scale digital device screens.

1.6 Organization of Chapters

The first introduction chapter provides an overview of the research and the problem statement. It outlines the importance of the study of Sinhala typeface design in the digital context, particularly for small-scale digital device screens. This chapter also discusses the lack of research in the area of digital Sinhala typography and the challenges in designing fonts for legibility on small screens.

The literature review chapter explores the background and context of the research. It delves into the history of digital Sinhala typography and the anatomical features of the Sinhala script. This chapter also examines the typographic theories of Latin fonts that relate to legibility and discusses their relevance to the design of Sinhala fonts.

The third chapter details the first experiment carried out to identify the relationship between letter anatomy and legibility. The experiment involved testing various features of Sinhala letters and their impact on legibility. The results of this experiment are presented and analyzed.

The fourth chapter focuses on the impact of anatomical changes to letters on the selected sample font, Noto Sans Sinhala. The experiment involved distorting and changing distinct visual features of the font and analyzing their impact on legibility. The results of this experiment are presented and analyzed.

The final chapter contains the conclusion which summarizes the findings of the research and provides an overall conclusion on the effectiveness of optimizing Sinhala typeface features for small-scale digital device screens. This chapter also discusses the implications of the study and its contribution to the field of digital typography. This chapter also provides suggestions for future research in the field of Sinhala typeface design and digital typography. It highlights areas that require further investigation and offers recommendations for improving the legibility of Sinhala fonts in the digital context.

1.7 Chapter One Summary

Chapter 01 of the research thesis "Sinhala Typeface Features to Optimize Readability for Small Scale Digital Device Screens" serves as an introduction to the research problem and aims to provide a background and context for the study. The chapter begins with a brief overview of the problem statement, which is followed by an explanation of why using fonts designed for printing on digital displays is not optimal, especially for the Sinhala script. The lack of literature specific to Sinhala scripts regarding legibility in the context of digital screens is also discussed.

The scope of the study is then defined, which focuses on the anatomical features of the Sinhala letter and digital fonts that are widely used in the contemporary context, especially in small-scale digital devices. The information sources for the research, including books, journals, research papers, and interviews, are also mentioned. The aim of the research is to identify the anatomical features of Sinhala typefaces that contribute to optimizing the legibility of small-scale digital device screens, while also identifying the role of general anatomical features of a script that contribute to designing a font for a purpose.

The chapter also discusses the methodology for the research, which involves reviewing the digital history of Sinhala fonts, exploring typographic theories of Latin fonts that relate to legibility, identifying the basic anatomical features of Sinhala fonts, experimenting with these features to determine their contribution to legibility, and analyzing existing fonts in Sinhala digital typography.

Finally, the chapter provides an overview of the organization of the thesis. Chapter 02 will be dedicated to the literature review, Chapter 03 will detail the methodology for the first experiment, Chapter 04 will describe the methodology for the second experiment, and Chapter 05 will provide the overall conclusion of the research.

CHAPTER 02: DIGITAL TYPOGRAPHY AND LEGIBILITY

2.1 Development towards digital typography

Typefaces have evolved significantly since the invention of the printing press in the 15th century. Early typefaces were created as metal blocks, with each block representing a single character. These blocks were arranged by hand to create text, and the process was both time-consuming and labor-intensive (Chapman, 2020). With the invention of the mechanical press in the 19th century, typefaces began to be produced as cast metal types, which could be used in a printing press and allowed for faster and more efficient printing (Roemer, 2018).

With the advent of the computer in the 20th century, typefaces have undergone further evolution. Digital typefaces and fonts were developed, which could be created and stored electronically, making them much easier to use and distribute. Early digital typefaces were limited in terms of design and functionality, but as technology advanced, so did the capabilities of digital typefaces.

One of the major innovations in digital typefaces was the development of the TrueType font format, which was created by Apple in the late 1980s and later adopted by Microsoft for use in Windows. TrueType fonts allowed for greater flexibility and control over the design of typefaces, and they could be easily scaled and manipulated on screen (Ali & Jacobs, 2020).

With the rise of the internet and mobile devices, typefaces have become increasingly important for digital media. Today, there are thousands of digital typefaces available for use on a wide range of platforms, including Windows, Mac, and mobile devices. These typefaces are optimized for use on different devices and are designed to be legible and easy to read on small screens.

In recent years, with the advent of web fonts, the use of typefaces in web design has become more prevalent and versatile, giving designers more control over how their websites look and feel, across different devices and platforms.

Overall, typefaces have undergone a significant evolution from their early origins in print media to their current state as digital typefaces and fonts, which are widely used on a variety of platforms, including computers, mobile devices, and the web.

2.1.1 An introduction to typography

Typography is the art and technique of arranging type, type design and modifying type glyphs. It is the visual component of written language and the design of typeface and the way it is arranged and presented on the page. It is a critical aspect of graphic design and plays a crucial role in the readability, legibility and overall aesthetic appeal of a design. It involves the use of various elements such as typeface, point size, line spacing, letter spacing, and color to create a cohesive and visually pleasing design. Through the use of typography, designers can convey tone, emotion and emphasis, and effectively communicate a message to their audience. It's an essential tool for designers and typographers, enabling them to create beautiful, legible and effective designs.

a) What is typography and explanation on basic terminologies

The field of typography has a specialized vocabulary that is used to describe the various elements and techniques involved in type design and layout. **A typeface** refers to the overall design of a font, including the shapes of the characters and the style of the serifs (if any) (Statz, 2018). **A font**, on the other hand, refers to a specific version of a typeface, such as bold or italic. A typeface may have multiple fonts.

The use of **serifs,** which are small lines or strokes added to the end of a character's main strokes, is a key aspect of typography. Serif typefaces are considered to be more traditional and are often used in print materials, whereas **sans-serif** typefaces, those without serifs, are considered to be more modern and are often used in digital media.

The **x-height**, which refers to the height of the lowercase letters,(Haley, n.d.) is a key element in the readability of a font. Leading, which pertains to the amount of space between lines of text, and **kerning,** which pertains to the amount of space between individual characters, are also critical elements in typography. **Ligatures,** which are special characters used to connect certain letter combinations for a more visually pleasing appearance, also play an important role in typography.

Tracking, which determines the amount of space between characters across a block of text, and hierarchy, pertains to the organization of type in a design to indicate importance and create a clear visual path for the viewer, are also important elements in typography. Finally, **contrast,** which relates to the relationship between the lightness and darkness of different elements in a design, is another key element in typography (Johnson, n.d.).

In summary, typography is a specialized field within graphic design that deals with the design, layout and manipulation of typefaces. It encompasses various elements such as typeface, point size, line spacing, letter spacing, and color to create a cohesive and visually pleasing design. The goal of typography is to improve readability, legibility and overall aesthetic appeal of a design and to effectively communicate a message to the audience. A specialized vocabulary is used in typography to describe the various elements and techniques involved in type design and layout. Understanding these terms and techniques can aid in the creation of more effective and visually pleasing designs.

b) Anatomy of Latin fonts

The anatomy of Latin fonts refers to the specific design elements and characteristics that make up the letterforms of a Latin typeface. These elements include the basic structure and form of the letters, as well as the details and variations that make each typeface unique (Stocks, n.d.).

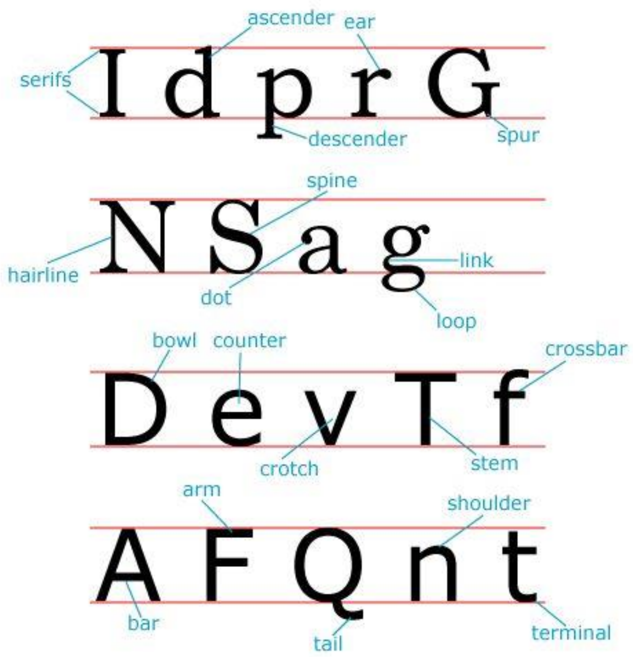


Figure 01: Anatomy of latin letters
Source: https://adammwood.com/2016/08/the-anatomy-of-a-letter-in-typography/

The basic structure of Latin letters can be divided into two main parts: the stem and the bowl. The stem is the vertical or diagonal main stroke of a letter, and the bowl is the curved or rounded part of a letter (Velarde, 2017). For example, in the letter 'o' the bowl is the circular shape that encloses the letter, while in the letter 'h' the bowl is the enclosed area created by the horizontal and vertical strokes of the letter.

In addition to the basic structure, Latin letters also have specific design elements such as the serif, the apex, the baseline, the x-height and the counter (Stocks, n.d.). The serif is the small line or stroke that is added to the end of a character's main strokes. The apex is the point where two strokes of a letter meet, such as the point of the letter 'A'. The baseline is the imaginary line on which the letters sit. The x-height is the height of the lowercase letters and it's an important aspect in readability of a font. The counter is the enclosed or partially enclosed space within a letter, such as the space within the letter 'o'.(Velarde, 2017)

In addition to these basic elements, Latin fonts can also have variations such as the weight (thickness or boldness) of the strokes, the slant (angle) of the letters, the spacing between letters and words, and the use of ligatures (special characters used to connect certain letter combinations). These variations can greatly affect the overall aesthetic and legibility of a typeface. It also creates an identity unique to each font (MasterClass, 2021).

c) The importance of typography in historical contexts (in graphic design trends) and how it plays a major role in the modern contexts:

Typography has played a significant role in the evolution of graphic design throughout history. In the early days of print media, typography was primarily used to convey information through text. However, as the field of graphic design evolved, typography began to be used as a tool for visual communication, and it began to play a major role in the design of printed materials such as books, newspapers, and magazines.

During the 19th century, the Arts and Crafts movement brought about a renewed interest in traditional typography and calligraphy, and this led to a renewed emphasis on the craftsmanship and beauty of typography. The advent of the 20th century saw the emergence of new design styles such as Art Nouveau and Art Deco, which brought about new typographic styles and techniques. (Perera, 2023)

In the mid-20th century, the Swiss Style of graphic design emerged, which emphasized clean, geometric forms and a strong emphasis on typography. This style had a major influence on graphic design and typography in the latter half of the 20th century. (Budrick, 2021)

Figure 02: Art deco fonts and Swiss style font posters
Source:https://randpophelvetica.tumblr.com

In the modern era, typography has become an increasingly important aspect of graphic design, particularly in the digital age. With the rise of the internet and mobile devices, typography has become an important tool for visual communication on the web and in digital media. Today, there are thousands of digital typefaces available for use on a wide range of platforms, including Windows, Mac, and mobile devices. These typefaces are optimized for use on different devices and are designed to be legible and easy to read on small screens.

Moreover, typography continues to play a major role in the field of graphic design, with a renewed interest in hand lettering, calligraphy, and the use of type as a form of visual expression. The rise of web fonts, which allows designers to use custom typefaces on websites, has also broadened the possibilities of typography in digital media.

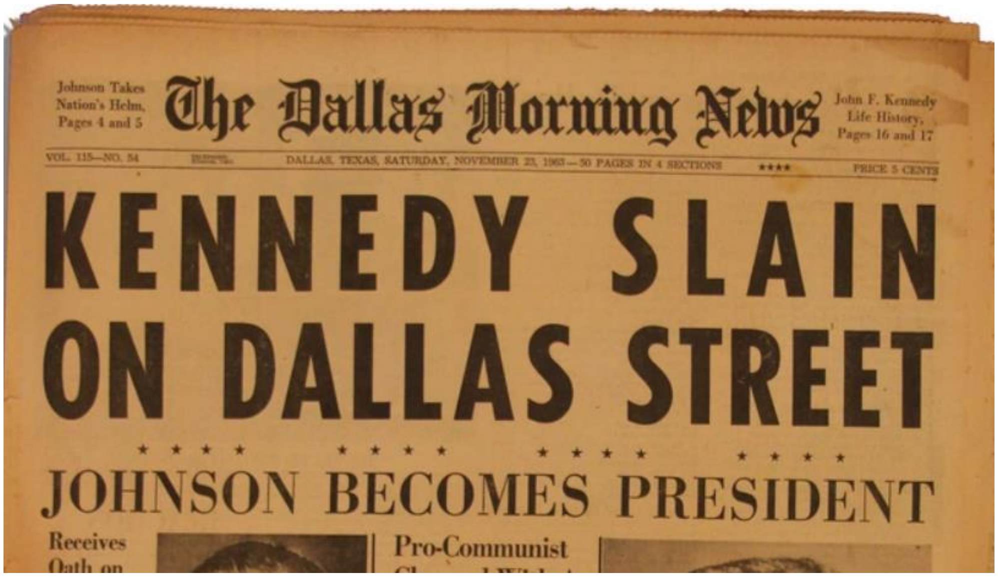
d) Digitization of information and platforms of digitization

Digitization of information refers to the process of converting analog information, such as text, images, and audio, into a digital format that can be stored, processed, and transmitted electronically (Arobs, 2022). This process involves the use of specialized software and hardware to capture, digitize, and store the information in a digital format, such as a text file, image file, or audio file.

The process of digitization begins with the capture of the analog information. This can be done using a variety of methods, such as scanning a printed document, recording audio using a microphone, or capturing an image using a digital camera (Xie & Matusiak, 2015). Once the information has been captured, it is then digitized. This involves the use of software and algorithms to convert the analog information into a digital format.

Digitization also allows for greater accessibility to the information, as digital files can be easily shared and distributed over the internet. This has led to the development of digital libraries, online archives, and other digital resources that make information more widely available to users around the world.

Digitization has had a significant impact on the field of typography, allowing for greater flexibility, control and precision in type design and layout. With the evolution of digital typefaces and fonts, designers have been able to create, edit and distribute typefaces more efficiently and with more precision than before. The use of digital tools such as font editors, have made it easier for designers to experiment with different forms and variations of letters, and the ability to easily manipulate type size and spacing, has allowed for greater control over the legibility and readability of type. Additionally, the rise of web fonts and the ability to use custom typefaces on websites has broadened the possibilities of typography in digital media.



Johnson Takes Nation's Helm, Pages 4 and 5

The Dallas Morning News

John F. Kennedy Life History, Pages 16 and 17

VOL. 115—NO. 54 DALLAS, TEXAS, SATURDAY, NOVEMBER 23, 1963—50 PAGES IN 4 SECTIONS PRICE 5 CENTS

KENNEDY SLAIN ON DALLAS STREET

JOHNSON BECOMES PRESIDENT

Receives

Pro-Communist

Figure 03: A printed font sample
Source: dallas-morning-news-nov-23-1963

Figure 4: A digital font sample

When considering the path of transformation of fonts from print media to digital media there were some major differences that occurred due to the technological improvements. First, digital platforms have a wider range of typeface options available. Digital fonts can be easily created and distributed, leading to a vast number of typefaces available for use on the web and in digital media, compared to the limited number of typefaces that were traditionally used in print media. This allows for greater flexibility and creativity in typography on digital platforms (Bigman, 2016).

Second, digital platforms have the ability to adjust type size and spacing in real-time, whereas print media is limited to the physical constraints of the printed page (Bigman, 2016). This allows for greater control over the legibility and readability of type on digital platforms, as designers can adjust type size and spacing to optimize readability on different devices and screen sizes.

Third, digital platforms have the ability to use dynamic typography, where type can change size, color, and spacing in response to user interactions or other variables. This allows for greater engagement and interactive experiences for the audience and finally digital platforms also have the ability to use web fonts, which allows designers to use custom typefaces on websites, broadening the possibilities of typography in digital media.

Overall, digital platforms offer greater flexibility, control, and precision in typography compared to print media, allowing for more innovative and engaging typographical designs.

2.1.2 Technical parameters of digital fonts

a) Screen resolution and DPI

In a typographical standpoint, screen resolution and DPI (dots per inch) are important factors that determine the quality and legibility of type on digital devices.

Screen resolution refers to the number of pixels that make up the display on a digital device. The higher the resolution, the more pixels that are used to display an image, which results in a sharper and more detailed image. In the context of typography, a higher screen resolution allows for smaller type sizes to be used while still maintaining legibility (Riemersma, n.d.).

DPI, or dots per inch, refers to the number of dots used to create an image or text on a digital device. A higher DPI results in a more detailed and clearer image. In the context of typography, a higher DPI allows for more precise rendering of type, which can improve the legibility and readability of text (Radich et al., 2022).

Together, screen resolution and DPI determine the overall quality and legibility of type on digital devices. A higher screen resolution and DPI will result in sharper and more legible type, while a lower resolution and DPI can make text appear pixelated or blurry, leading to difficulty in reading. Therefore, designers should take into consideration the screen resolution and DPI of their target devices when creating typographic designs (Kumar, 2023).

b) Different types of Encoding Standards

Encoding standards for fonts refer to the methods used to map the characters of a font to specific code points in a character set or encoding. This mapping allows for the accurate display and representation of characters on digital devices. There are several different encoding standards for fonts, each with their own advantages and limitations.

Unicode is a widely used encoding standard for fonts. It is a standardized system for encoding and representing text in different scripts and languages, and it allows for the representation of a large number of characters, including those used in most written languages. Unicode also includes a set of standardized code points for commonly used symbols, emojis and other special characters.

ASCII (American Standard Code for Information Interchange) is an older encoding standard that assigns a unique code point to each character in a font. It only includes a limited number of characters, mostly limited to the english alphabet, numbers and some symbols. Most older fonts were based on the ASCII encoding method (Loshin, 2021).

UTF-8 is a widely used encoding standard that is based on Unicode. It is a variable-length encoding system that uses a small number of bytes to represent the most common characters and a larger number of bytes to represent less common characters. This allows for efficient storage and transmission of text, as well as compatibility with older systems that do not support Unicode.

ISO-8859-1 is an encoding standard that is commonly used in Western European languages. It includes code points for common punctuation and special characters, but it does not include support for characters used in other scripts or languages (Huang, 2019).

Windows-1252 is an encoding standard that is commonly used on Windows systems. It is based on ISO-8859-1, and it includes additional code points for common punctuation and special characters that are not included in ISO-8859-1 (Injosoft AB, http://www.injosoft.se, n.d.).

Each of these encoding standards has its own advantages and limitations but currently the Unicode encoding method is considered as the international standard for encoding fonts (Unicode Standard, n.d.). As for the Sri Lankan context, Sri Lanka first had a non-Unicode keyboard based encoding. This was later changed when Sri Lanka first adapted its first encoding standard known as SLASCII, approved by the Sri Lanka Standards Institute as SLS 1134 in 1996. Sri Lanka currently adopts Unicode [4] Version 3.0. SLS 1134 which was revised in 2001 (Dias, 2005)

c) True-type and Mono-type variables

TrueType and Monotype are two different font formats that are used in typography. TrueType fonts are scalable and use Bézier curves to define the shape of the characters, while Monotype fonts are bitmap fonts that do not scale well and can suffer in quality when resized (Rickner, 2016). TrueType is widely supported and compatible, making it a popular font format for digital typography, whereas Monotype is not as commonly used in modern digital typography (Shimada, 2006).

TrueType is a font format that was developed by Apple and Microsoft in the late 1980s. It is a scalable font format, which means that the font can be resized and still retain its shape and quality (Lupton, 2010). TrueType fonts use Bézier curves to define the shape of the characters, which allows for greater precision and control in the design of the characters. TrueType fonts are also supported by a wide range of operating systems and devices, making them a widely compatible font format.

Monotype, on the other hand, is a font format that was developed by Monotype Corporation in the early 20th century (Bryans, 2019). It is a bitmap font format, which means that the font is made up of a set of fixed-size images, called bitmaps, that represent the characters. Because of this, Monotype fonts do not scale well, and the quality of the font can suffer when it is resized. Monotype fonts are also not as widely supported as TrueType fonts, and they are not as common in modern digital typography (Bigelow, 2020).

d) Usage of operating systems/platforms and their technology for digital typography

Windows operating systems, for example, have built-in support for a wide range of font formats, including TrueType and OpenType fonts. Windows also has a feature called ClearType, which is a technology that is designed to improve the legibility of text on LCD screens (Chaparro et al., 2010). Additionally, Windows operating systems also support the use of custom fonts and allow for easy installation and management of fonts.

MacOS, on the other hand, has built-in support for TrueType and OpenType fonts, and also supports the use of custom fonts. MacOS also has a feature called "Apple Advanced Typography" (AAT), which is a technology that is designed to improve the display of complex scripts, such as Arabic and Chinese (Williams, 2003).

Linux operating systems also have built-in support for a wide range of font formats, including TrueType and OpenType fonts. Linux also has built-in support for font management and allows for the easy installation and management of fonts (White, 2015).

In mobile operating systems such as iOS and Android, support for different font formats can vary. Both iOS and Android have built-in support for TrueType and OpenType fonts, but they also have support for custom fonts. However, there may be limitations on which font formats can be used for different versions of the operating systems and devices (Bala et al., 2015).

Operating systems have adapted for more user-friendliness is by implementing technologies that improve the legibility of text on digital screens. For example, Windows operating systems have ClearType, which is a technology that is designed to improve the legibility of text on LCD screens and “AAT” (Apple Advanced Typography) , which improves the display of complex scripts.

Operating systems have also adapted by including more typefaces that are designed to improve legibility. For example, Windows operating systems include a number of typefaces that are specifically designed to be more legible on digital screens, such as Segoe UI and Calibri (Erickson, 2013). MacOS also includes typefaces such as Helvetica Neue and San Francisco, which are specifically designed to be more legible on digital screens (Morson, 2015).

Additionally, operating systems have also implemented features such as dynamic type, which automatically adjusts the size and spacing of text based on the device or screen size. This allows for better legibility on different devices and screen sizes.

2.2 Digital typefaces and Legibility

With the popularization of digital platforms, there has been a growing demand for legible fonts. This has led to the development of new typefaces specifically designed to improve legibility in digital media. Research has shown that legibility is a critical factor in digital typefaces, as it plays a significant role in ensuring that text is easily readable on digital platforms. Studies on the effectiveness of different typefaces have demonstrated that legibility is an important aspect of design, particularly when it comes to digital media. As such, designers and typographers should prioritize legibility when creating typefaces for digital platforms in order to enhance the user experience.

2.2.1 What is legibility

Legibility, as Walter Tracy defines, is the quality of being easy to read. He further explains that this term means the quality of being decipherable and recognizable in a typographical context. Legibility refers to perception and the measure of legibility is the speed of which a character is recognized. (Tracy, 1986) Beier and Larson states that the reading is a continuous process which makes use of foveal and parafoveal vision. Also they have identified some key factors such as character differentiation, contrast, stroke angle, weight, width, resolution and hinting which affect the legibility of a letter. (Larson, 2010) Legros and Grant have defined 12 features that affect legibility in printing surfaces. Amongst them, the two factors: Size of the characters and the resemblance can be more impactful in the context of digital displays since these displays contain a lot of information in a confined space (mostly computer or mobile device screens). They also suggest the method of superimposing letters to observe the differences between the anatomic structure. (Grant, 1916)
“The investigation of what constitutes legibility in type presents many difficulties, for it depends essentially on two main heads: (1) the subjective, or the view of the reader; and (2) the objective, or the features presented by the printed surface to be read” (Legros, 1922, p.1).

a) Methods of measurement

There are several methods for measuring legibility in typographic literature. The most common methods are:

1. Visual Acuity Test: This method measures the smallest size at which a person can read a text with a certain level of accuracy. The text is presented at various sizes, and the size at which the person can read the text with a certain level of accuracy is recorded. This method is used to determine the minimum size at which a typeface can be used for a specific application (Arditi, 2004).
2. Reading Speed Test: This method measures the time it takes for a person to read a text at a specific size. The text is presented at a fixed size, and the time it takes for the person to read the text is recorded. This method is used to determine the maximum reading speed that can be achieved with a specific typeface (North & Jenkins, 1951).
3. Character Recognition Test: This method measures the time it takes for a person to recognize individual letters or characters. The characters are presented in a random order, and the time it takes for the person to recognize each character is recorded. This method is used to determine the legibility of individual letters or characters within a typeface (Bigelow, 2019b).
4. Word Recognition Test: This method measures the time it takes for a person to recognize words. The words are presented in a random order, and the time it takes for the person to recognize each word is recorded. This method is used to determine the overall legibility of a typeface (Juhasz & Rayner, 2006).
5. Subjective Evaluation: This method is based on the opinions and perceptions of the viewers. Participants are asked to rate the legibility of a typeface on a scale, or to provide written feedback on the legibility of a typeface (Hannah, 2022).

Each method has its own advantages and disadvantages and different methods can yield different results. It is important to note that legibility is a complex phenomenon and the results of the legibility tests can be influenced by factors such as the design of the typeface, the context in which it is used, and the viewer's characteristics (Sheedy et al., 2005). Therefore, it is important to use multiple methods and to consider the results in the context of the intended use of the typeface.

b) Metrics of measurement

The most commonly used metrics to measure legibility in text include:

1. Legibility Index: This metric is calculated by dividing the reading speed by the visual acuity. A higher legibility index indicates that a typeface is more legible.
2. Character Recognition Score: This metric is calculated by dividing the number of correctly identified characters by the total number of characters presented. A higher character recognition score indicates that a typeface is more legible.

3. Word Recognition Score: This metric is calculated by dividing the number of correctly identified words by the total number of words presented. A higher word recognition score indicates that a typeface is more legible.
4. Subjective Evaluation Score: This metric is based on the opinions and perceptions of the viewers. Participants are asked to rate the legibility of a typeface on a scale, or to provide written feedback on the legibility of a typeface, and these results are used to calculate a subjective evaluation score.
5. Error rate: This metric is calculated by dividing the number of misread letters by the total number of letters presented. An Error rate is often used in legibility testing for people with reading difficulties, as it is thought to be a more accurate way to measure the effectiveness of a typeface for this population.

It is important to note that these metrics are not mutually exclusive, and a combination of metrics may be used to provide a more comprehensive assessment of legibility. Additionally, different metrics may be more appropriate for different types of text or different contexts. For example, reading speed may be more important for body text, while character recognition may be more important for signages.

c) How legibility affects the contexts of digital media with special reference to digital screens

One of the main challenges of legibility on digital screens is the limited resolution of the screens (Sawyer et al., 2020). has demonstrated that smaller screens, such as those on smartphones, have a lower resolution than larger screens, such as those on computers. This can negatively impact the legibility of text on smaller screens, particularly when the text is small or the typeface is complex. To address this issue, designers should consider using larger font sizes and simpler typefaces for text on smaller screens.

Another challenge of legibility on digital screens is the viewing distance. Digital screens are often viewed from a closer distance than print materials (Bababekova et al., 2011), which can make it more difficult to read text on digital screens especially such as mobiles. Studies have shown that increasing the font size can mitigate this issue, thus designers should consider using larger font sizes for text on digital screens. But this solution will not always be applicable in some cases where there is a large volume of text and the space allocated for text is rather small such as in a mobile web page.

Ambient lighting can also have a significant impact on legibility on digital screens. Research has indicated that bright ambient light can wash out the text on the screen, making it difficult to read, while low ambient light can make the text appear too dark (Grant, 1916). To address this issue, designers should consider using high-contrast typefaces and adjusting the brightness and contrast settings on the screen.

Furthermore, the type of device and its intended use also plays a role in legibility on digital screens. Studies have shown that legibility can vary based on the type of device (Beier, 2012), and a typeface that is legible on a computer screen may not be legible on a small smartphone screen. In addition, the intended use, such as an e-book or a website, can also affect legibility. Therefore, it's important to choose the right typeface for the intended medium and purpose of the design and to test the legibility of the typeface in the context in which it will be used.

Digital screens present unique challenges for legibility and designers should take into account factors such as screen resolution, viewing distance, ambient lighting, and the device and intended use when creating typefaces for digital media to enhance the user experience.

d) Case studies on how special fonts were optimized with legibility as the main factor

A key fact that must be understood is that optimization of a font to perform in a niche platform or a context follows a specific methodology in each case. Optimization parameters of a typeface to do a specific job can be heavily dependent on the specific context. For example, a typeface which is optimized for print media does not take some parameters into consideration such as anti-aliasing which is used in fonts made for digital media. (Boyarski, 1998) In the same manner, typefaces may have different optimization parameters in the same specific context but vary according to the job. In this way, two digitally optimized typefaces for the same digital displays may have differently optimized parameters according to the objective of that typeface. (Eg: A font optimized for small screen body text on websites may differ from a font optimized for digital road signs. Both are made for digital displays, but their objective is different.) These same category fonts show common characteristics among themselves than a font designed for a different media like print. (Beier, 2012) FF Meta is one such typeface family where this context specified design is addressed. *'FF InfoText'* is a typeface designed for small body texts while *'FF InfoDisplay'* is designed for larger spaces like signages. Both typefaces have different anatomical features but follow a consistent design.

Context specific optimization of a font can be done in many ways ranging from more technological aspects like hinting and OS support to design oriented aspects like anatomy. These optimizations are done to increase legibility while keeping the consistency and aesthetics across the letters. Maintaining legibility is a crucial task in a context like digital screens where the font size is small (8pt – 12pt) (Ziefle, 2010).

In recent years, there has been a growing interest in the design of typefaces specifically for use on digital screens. These typefaces, known as digital typefaces, are designed to improve legibility and readability on digital screens, taking into account factors such as screen resolution, viewing distance, and usage platform. Two such fonts that are specifically optimized for the digital screen are **Georgia** and **Verdana** fonts (Banerjee & Bhattacharyya, 2011). This section of the research briefly discusses the case studies of each font and how they were created in order to maximize the legibility when used in the context of digital screens.

i. Georgia

The font Georgia is a digital typeface that was specifically designed for use on digital screens. Developed by Matthew Carter in 1993, Georgia was commissioned by Microsoft and was included as a default font in the Windows operating system.

Figure 5 : Georgia Font sample

One of the main design goals of Georgia was to create a typeface that would be legible and easy to read on digital screens. To achieve this, Carter used a larger x-height (the height of lowercase letters) and wider spacing between letters and words compared to traditional typefaces. This design decision was based on research that showed that larger x-heights and wider spacing improved legibility on digital screens.

In addition to its legibility-enhancing design, Georgia also has a more traditional, serif design. Carter drew inspiration from traditional serif typefaces such as Garamond and Caslon, but he also incorporated design elements that were specifically intended to improve the look of the font on digital screens. For example, he used a more rounded design for the serifs, which helped to make the font look less jagged on low-resolution screens.

Georgia was also designed to be highly readable at small sizes. Carter used a technique called hinting, which is a process that improves the appearance of text at small sizes by adjusting the shapes of the letters to better align with the pixels on a screen. This allowed for Georgia to maintain its legibility at small font sizes.

The Georgia font quickly became popular among web designers and typographers, due to its legibility and its traditional serif design which give it a classic and elegant look. It is used extensively in print and digital media, from books, newspapers, and magazines to websites, and other digital platforms.

In conclusion, the font Georgia is a digital typeface that was specifically designed for use on digital screens. Its design goals were to create a typeface that would be legible and easy to read on digital screens by using a larger x-height

ii. Verdana

Verdana is a popular font that was specifically designed for use on digital screens similar to Georgia. Developed by Matthew Carter in 1996, Verdana was commissioned by Microsoft as part of their effort to improve the legibility of text on computer monitors.

Figure 5 : Verdana Font sample

One of the main challenges in designing a digital font is that the resolution of digital screens is much lower than that of printed materials. This can make it difficult to create a font that is both legible and aesthetically pleasing.

Verdana was designed to overcome this challenge by using a larger x-height (the height of lowercase letters) and wider spacing between characters. This allows the letters to be more easily distinguished from one another, even on low-resolution screens. In addition, Verdana's letters have a slightly condensed shape which also increases the space between letters, making them easier to read.

The font also includes a number of other design features that enhance legibility on digital screens. For example, the letters have a relatively simple design with minimal serifs, which reduces the risk of blurring on low-resolution screens. Additionally, the font includes unique shapes for certain letters such as the lowercase 'g' and 'a' which makes them easier to read.

Verdana's design was well-received and the font has been widely adopted for use on digital screens, particularly on websites and in applications. Its legibility on digital screens and its simple design make it an ideal font for use in digital environments, especially for body text.

In conclusion, Verdana was designed as a digital font specifically to increase legibility on digital screens. Its design features such as larger x-height, wider spacing and minimal serifs, as well as unique shapes for certain letters, make it a font that is easy to read on digital screens, making it an ideal font for body text on digital platforms.

e) Importance of legible fonts in the present day especially in digital media, and how it helps to reduce the sensory overload.

In the present day, the importance of legible fonts in digital media has become increasingly significant. With the rise of digital devices and the internet, people are exposed to an overwhelming amount of information on a daily basis. This increase in the amount of information can cause what is known as "sensory overload," which can lead to difficulty in processing and understanding the information.

One way to mitigate sensory overload is through the use of legible fonts (Salingaros, 2003). Legible fonts are those that are easy to read and understand, and they are designed to improve the clarity and readability of text. This is particularly important in digital media, where text is often displayed on small screens and at low resolutions.

Legible fonts are designed using specific principles, such as the use of larger x-height, wider spacing between letters and words, and the use of serifs or other design elements that improve the appearance of text on digital screens (Bigelow, 2019). The use of legible fonts can make text easier to read and understand, which can help to reduce the cognitive load on the reader and make it easier for them to process and understand the information.

Furthermore, the use of legible fonts can also improve the overall user experience on digital platforms. Legible fonts can make it easier for users to navigate and interact with digital media, which can lead to increased engagement and satisfaction (Vinot & Athenes, 2012).

f) How legibility affects the reading speed of a font

Legibility of a font can have a significant impact on reading speed (Arditi & Cho, 2005). Legible fonts are designed to be easy to read and understand, and they are typically characterized by features such as a larger x-height, wider spacing between letters and words, and the use of serifs or other design elements that improve the appearance of text on digital screens (Hojjati & Muniandy, 2014). These design elements can make text easier to read and understand, which can lead to faster reading speeds. One of the main reasons for this relationship is that legible typefaces make it easier for the reader to identify individual letters and words. This allows the reader to quickly and accurately decode the text, which in turn allows for faster reading speeds (Young, 2014).

Another reason for the relationship between legibility and reading speed is that legible typefaces often have appropriate spacing between letters and words (Soleimani & Mohammadi, 2012). This helps to improve the readability of the text and allows the reader to quickly and accurately process the text. Typefaces with appropriate spacing between letters and words are considered more legible than those with cramped spacing, and thus can result in faster reading speeds (Arditi & Cho, 2005).

Research has shown that legible fonts can lead to faster reading speeds because they make it easier for readers to identify and distinguish individual letters and words (Beier, 2012). This can reduce the cognitive load on the reader and make it easier for them to process and understand the information. Additionally, legible fonts can also reduce the need for re-reading and fixations, which can further increase reading speed.

g) Importance of identifying the factors affecting the legibility of fonts

In the field of typography, legibility is a crucial aspect that determines the ease of reading and understanding text. Understanding the factors that affect legibility is crucial for designers, typographers, and user experience professionals in order to create effective and efficient designs that are easy to read and understand.

Identification of the factors affecting legibility of fonts allows designers to create typefaces that are optimized for specific contexts and mediums. For example, a typeface that is legible on a computer screen may not be legible on a small smartphone screen, and understanding the factors that affect legibility in these contexts can help designers create typefaces that are appropriate for each medium.

It also helps to ensure that the text is easily readable and understandable, which can enhance the user experience. Poor legibility can make text difficult to read, which can lead to frustration and confusion, particularly when used in contexts such as signages, websites or e-books. This can also aid in the selection of typefaces for specific projects or applications. Identifying the factors that affect legibility can help designers to select typefaces that are appropriate for the intended use and context of the design.

Another main importance is that the identification of these factors properly can be useful for creating accessible designs. It can help designers to create typefaces that are accessible to people with visual impairments or reading difficulties.

These factors can aid in the evaluation of existing typefaces. Identifying the factors that affect legibility can help designers to evaluate existing typefaces and to determine if they are appropriate for a specific project or application.

h) Factors which affect the legibility of Latin fonts.

Beier and Larson state that the reading is a continuous process which makes use of foveal and parafoveal vision. Also, they have identified some key factors such as character differentiation, contrast, stroke angle, weight, width, resolution and hinting which affect the legibility of a letter. (Larson, 2010) Legros and Grant have defined 12 features that affect legibility in printing surfaces.

1. Size of the characters
2. Amount of space between succeeding lines (leading)
3. Amount of white between the main strokes or counters
4. Length of the printed line
5. The resemblance of some characters to others
6. Presence of unnecessary lines and marks, ornamental or otherwise
7. Frequency of kerns
8. Quality of paper and color
9. Color of the ink
10. Capacity of paper for reflecting light
11. Illumination
12. Irradiation

Amongst them, the two factors: Size of the characters and the resemblance can be more impactful in the context of digital displays since these displays contain a lot of information in a confined space (mostly computer or mobile device screens). Some factors like illumination and irradiation also can be affecting the digital screens but they relate to a technological category rather than anatomical differences. Also, the properties of the paper can be converted into properties of the screen for comparison purposes, but more research must be needed to confirm this. Given that the scope of this research is limited to the anatomical properties of letters, only these properties will be taken into consideration due to the fact that research is based on typography and anatomical features affect legibility more in comparison to other factors.

The Latin fonts Georgia and Verdana have been designed with keeping these above factors in mind. That is why those typefaces have a very high legibility even in small screens like mobile interfaces (Rello et al., 2016). But in the local context, there are no Sinhala fonts that have been designed specifically for digital displays. With the lack of research done for local fonts, it is hard to directly define the features that must be included for a Sinhala font to be successful in digital displays. In the initial process of understanding the required typographic features that must be included in a Sinhala font for digital displays, anatomical features that increase legibility take a primary role.

2.3 Role of legibility in letter misidentification

Legibility in typefaces is a critical aspect that can be optimized through various methods. While many factors can affect legibility, analysis through the method of letter misidentification is considered to be the most optimal approach. This is because, from a type design perspective, the letter feature is the most important aspect of a typeface (Bigelow, 2019). In order to experiment and make adjustments to letter features, the method of analyzing similar letter misidentification in small digital screens is deemed to be the most appropriate and effective approach. (Beier, 2012) This method allows for a detailed examination of the legibility of a typeface, by specifically identifying and addressing any issues related to the confusion or misinterpretation of letters or characters when used on small digital screens. Thus this research narrows in on focusing letter misidentification as its main factor.

2.3.1 Relationship between legibility and letter misidentification

Letter misidentification in the context of typography refers to the confusion or misinterpretation of letters or characters in a typeface. It occurs when the design of the letters or the spacing between them makes it difficult for the reader to distinguish between them, leading to confusion or misinterpretation (Pelli et al., 2006). This can negatively impact the readability and understanding of text, making it more difficult for the reader to process the information.

In some cases, letter misidentification can also occur due to the use of typefaces that are not appropriate for the intended medium or context. For example, a typeface that is legible on a computer screen may not be legible on a small smartphone screen, which can lead to letter misidentification. Similarly, typefaces that are not designed for use in low-light conditions can also lead to letter misidentification (Bigelow, 2019).

It's important to note that certain populations may be more susceptible to letter misidentification than others. For example, people with visual impairments or reading difficulties may have a harder time distinguishing between letters, particularly if the typeface is not designed with accessibility in mind (Vellutino et al., 2004).

The amount of letter misidentification present in a specific font also changes according to the script used. For example the number of misidentified letters of Latin fonts may vary drastically with the number of misidentified fonts in Sinhala scripts.

2.3.2 Latin anatomical features affecting letter misidentification

In the field of typography, legibility is a crucial aspect that determines the ease of reading and understanding text. However, poor legibility can also lead to problems with letter misidentification. Letter misidentification refers to the confusion or misinterpretation of letters or characters in a typeface, and it can have a significant impact on the readability and understanding of text. One of the main causes of letter misidentification is poor legibility, which can be caused by various factors such as the design of the letters, spacing between letters, and the medium or context in which it is used. In this section, we will explore the Latin font anatomical features that can greatly affect letter misidentification.

The anatomical features of a font can greatly affect letter misidentification. Some of the key features that can impact legibility and the potential for letter misidentification include:

1. Serifs: The presence or absence of serifs, which are the small lines or flourishes that extend from the ends of some letters, can affect the legibility of a font. Serifs can help to distinguish between similar letters, such as the letter "l" and the number "1", but can also make letters look more similar, such as "I" and "l" on some serif fonts.
2. Stroke width: The width of the strokes that make up the letters can also affect legibility. Thin strokes can make letters appear too similar, while thick strokes can make them appear too distinct and hard to read.
3. Counter: The space enclosed by a letter, such as the circular or oval space within letters like "o" and "e", can also affect legibility. Counters that are too small or too large can make letters appear too similar or too distinct.
4. Ascenders and Descenders: The height of the letters can also affect legibility. Letters with long ascenders or descenders, such as "b" and "d", can make it difficult to distinguish between similar letters, such as "b" and "d", "p" and "q"
5. Diacritics: The presence of diacritics, such as accent marks, can also affect legibility. Some typefaces may not have well-designed diacritics, making it difficult to distinguish between letters with and without diacritics.

a) Effect of font resemblance on letter misidentification

The resemblance of a font can have a significant effect on similar letter identification. When two or more letters in a font resemble one another, it can make it difficult for readers to distinguish between them, leading to letter misidentification. This can occur when the letters have similar shapes, or when they have similar features such as serifs, strokes, or counters (Biemiller, 1977).

The visual perception of written text is a complex process that is influenced by a number of factors, including the font used. One aspect of font design that has been shown to have a significant impact on the legibility of text is the resemblance of letters within a font (Candello et al., 2017).

A number of studies have investigated the impact of font resemblance on similar letter identification. These studies have consistently shown that font resemblance can lead to problems with similar letter identification, particularly in situations where the font is small or the text is viewed from a distance. For example, a study by Tjan, Loula, & Legge (2002) found that when a font with high letter resemblance was used, participants were more likely to make errors in letter identification, particularly when the font size was small.

This problem can be particularly challenging for individuals with visual impairments or reading difficulties, as they may have a harder time distinguishing between similar letters. For example, a study by Legge, Bigelow, & Ware (1987) found that individuals with visual impairments were more likely to make errors in letter identification when presented with a font with high letter resemblance, compared to a font with low letter resemblance.

To address this issue, font designers can create designs that minimize resemblance between letters. This can be achieved by using distinct shapes for letters, or by using different features such as serifs, strokes, or counters. For example, a study by Tjan, Loula, & Legge (2002) found that when a font with low letter resemblance was used, participants were less likely to make errors in letter identification.

b) How Latin fonts counteract font resemblance through anatomy

A number of studies have investigated the impact of font resemblance on similar letter identification. These studies have consistently shown that font resemblance can lead to problems with similar letter identification, particularly in situations where the font is small or the text is viewed from a distance (Mueller & Weidemann, 2012).

To counteract font resemblance and improve the legibility of text, font designers have developed various strategies to minimize resemblance between letters within a font. One such strategy is to use the anatomy of the letters to create distinct shapes for each letter. This can be achieved by manipulating the proportions, angles, and curvatures of the letters, as well as their serifs, strokes, and counters.

For example, Latin fonts such as Garamond and Bodoni, are known for their elegant and distinct shapes that are created by manipulating the proportions, angles, and curvatures of the letters. These fonts have relatively small x-height and high contrast between thick and thin strokes, which helps to create distinct shapes for each letter, reducing font resemblance and improving legibility.

Another strategy is to use different variations or variations of the same letter across different words, this is known as contextual alternates (Laufer, 1998). This is achieved by creating different variations of the same letter that are activated depending on the context of the word. This allows for the same letter to have different variations and shapes in different words, which helps to reduce font resemblance and improve legibility.

2.3.3 Test methods to carry out legibility testing by identifying letter misidentification tendency in Latin letters

Legibility testing is a crucial step in the design of written materials to ensure that the text is easily readable for the intended audience. One of the key aspects of legibility testing is identifying the tendency for letter misidentification within a font. This can be particularly challenging for Latin letters, as they often have similar shapes and features, making it difficult for readers to distinguish between them. There are 3 main methods of legibility testing. (Bigelow, 2019)

a) Distance testing

Distance testing is a type of legibility testing that involves measuring the distance at which individuals can read text in a particular typeface. This method is often used to test the legibility of fonts on signs, billboards, and other large-scale displays.

To conduct a distance testing study, researchers typically create a series of signs or displays with text in the font being tested. Participants are then asked to stand at various distances from the signs and indicate when they can no longer read the text. The distance at which participants can no longer read the text is recorded as the "legibility distance" for that font.

Distance testing can provide valuable insights into the legibility of a font in real-world scenarios, such as on highway signs or billboards. However, it may not provide as much detail on the specific factors that are affecting legibility, such as letter spacing, stroke width, or x-height. Therefore, it is often used in combination with other legibility testing methods to provide a more complete picture of a font's legibility.

b) Short exposure method

Short exposure testing is a legibility testing method that involves briefly exposing participants to a series of letters or words in a particular typeface. This method is often used to evaluate the legibility of fonts for small text sizes, such as those used on computer screens or in print materials.

In short exposure testing, participants are typically presented with a series of letters or words in the font being tested for a very short amount of time, typically a fraction of a second. Participants are then asked to identify the letters or words they saw. This process is repeated with different letter or word combinations, and the accuracy of participant responses is recorded.

By using short exposure testing, researchers can evaluate the legibility of a font based on its ability to be quickly and accurately perceived by the viewer. This method can provide valuable insights into the specific features of a font that may be affecting its legibility at small sizes, such as letter spacing, stroke width, or x-height.

c) Parafoveal vision testing

Parafoveal testing is a legibility testing method that assesses the ability of a font to be quickly and accurately read as the viewer's eyes move across a line of text. This method is designed to evaluate the legibility of fonts for reading longer passages of text, such as in books, articles, or web pages.

In parafoveal testing, participants are typically presented with a series of lines of text in the font being tested, and are instructed to read the text as quickly and accurately as possible. Eye-tracking technology may be used to monitor the viewer's eye movements as they read, allowing researchers to evaluate the font's legibility based on factors such as reading speed, fixation duration, and saccadic eye movements.

By using parafoveal testing, researchers can gain insights into the specific features of a font that may affect its legibility during prolonged reading, such as line spacing, kerning, or the overall visual density of the font. This method can also help identify potential areas of visual distraction or confusion within a font, such as inconsistent stroke widths or unusual letterforms.

2.3.4 Legibility issues in small digital screens

Legibility is an essential factor in typography, as it affects the readability and comprehension of text. In the context of digital media, legibility becomes even more critical due to the widespread use of mobile devices with small screens. As screen sizes decrease, legibility becomes a challenge, leading to potential readability issues for users (Lin et al., 2013). Legibility issues in small digital screens can be attributed to various factors such as low resolution, poor contrast, and limited screen size (Khagwal, 2021).

Low resolution is a significant factor that affects the legibility of typefaces in small screens. With lower resolution, the shapes of letters become less distinct, leading to blurred edges and reduced legibility (Habeeb, 2020). Poor contrast is another issue that affects legibility in small screens. The contrast between the text and the background should be sufficient to ensure legibility, especially in low light conditions. Limited screen size is also a critical factor that affects the legibility of typefaces. The smaller screen size restricts the amount of text that can be displayed, leading to the use of smaller font sizes, which can be difficult to read.

To address these legibility issues in small digital screens, designers have developed new typefaces and optimized existing ones. Typefaces that are optimized for small screens are designed with larger x-heights, wider letter spacing, and simplified letterforms to enhance legibility. Moreover, designers must ensure that the contrast between the text and background is adequate and that the font size is appropriate for the screen size.

In conclusion, this section highlighted the crucial role of core letter features in font legibility and similar letter misidentification. The design of individual letters and the unique features of each letter can have a significant impact on the ease with which text is read on small digital screens and the likelihood of similar letters being confused. Legibility testing methods can be employed to evaluate the readability of fonts, but it is important to take into account the specific letter features of each font when analyzing results. Moreover, it is vital to study the letter features of scripts that differ from the Latin script in order to better understand how these features affect legibility and similar letter misidentification under the context of digital screens. By paying close attention to core letter features, designers can optimize font legibility and enhance reading experiences for all and even use these methods for non-latin scripts.

Understanding the core letter features that impact font legibility and similar letter misidentification is essential for designing effective fonts for digital screens. However, this is just one aspect of the broader field of font design, which encompasses a wide range of scripts and languages. The Sinhala font industry is a prime example of the unique challenges and opportunities involved in designing fonts for non-Latin scripts. By examining the history of the Sinhala font industry and the process of digitizing print fonts, we can gain a deeper appreciation for the complexity of font design and the ongoing efforts to create legible and effective fonts for diverse scripts and languages. As digital screens continue to play an increasingly important role in our daily lives, the need for effective font design will only continue to grow, making it a vital area of study for designers and researchers alike.

2.4 Digitization of Sinhala typefaces

The Sinhala font industry has a long and fascinating history that spans centuries. Sinhala is the language spoken by the majority of the population in Sri Lanka and has a unique script that is derived from the Brahmi script. Over the years, the Sinhala font industry has evolved from traditional hand-carved letters to digitally created fonts. In this section, the history of the Sinhala font industry and its digitization phase is explored, with a special emphasis on how print fonts were digitized.

2.4.1 Evolution of Sinhala font industry and its digitization phase with a special emphasis on how print fonts were digitized

The early Sinhala fonts used in printing were based on calligraphic styles and were developed by the early printers. These fonts were primarily used for printing books, newspapers, and other printed materials. The digitization of the Sinhala font industry began in the early 1980s with the introduction of digital technologies in the printing industry. The first digital fonts were developed by companies such as Microimage, which used computer software to create digital versions of the traditional Sinhala fonts.

The digitization of Sinhala fonts in the 1980s was a significant milestone in the history of Sri Lankan typography. It marked the transition from traditional, manual methods of font design and production to digital technology. This transition opened up new possibilities for typography, making it possible to design and produce fonts with greater speed, accuracy, and flexibility.

A company that played a significant role in the digitization of Sinhala fonts was Microimage. Founded in 1984, Microimage was one of the pioneers in the field of computer graphics in Sri Lanka. They developed their first Sinhala digital font, called "MICR Sivam," in 1985. The font was designed using a custom-built software program, which allowed them to create the complex shapes and ligatures required for Sinhala typography.

Being celebrated as the most prominent digital font designer in Sri Lanka who has made a collection of fonts, Pushpananda Ekanayaka was another pioneer of taking the status of Sinhala typography to a novel level. Being the creator of the FM Malithi typeface, along with Ababld, Arjunn x, Basuru x, Bindumathi x, Derana x, Gemunu x, Gurulugomi and many more; his contribution to the Sinhala typography industry is unmatched (Pushpananda Ekanayaka - Sinhala Fonts, n.d.).

There were ten fonts that Mr. Ekanayaka created and released in 1998, which did not include a text typeface font. As a text font was highly required, Mr. Ekanayake created the highly well-liked FMAbhaya Sinhala ASCII font. After that, it became necessary to create and develop Sinhala typefaces in a variety of styles for a variety of uses. As a result, he created and developed 12 different Sinhala font designs (Mr. Pushpananda Ekanayaka, Internet Archive, 2020).

The most commonly used Sinhala typeface on the planet, FM Abhaya by Pushpananda Ekanayake, was released by Google Fonts as Abhaya Libre in 2016. According to the company's website, Sol Matas created a brand-new and original Latin for it. Matas and Ekanayaka received assistance from Pathum Egodawatta and Ayantha Randika for the Opentype engineering. Mooniak, a group of Sri Lankan designers and artists, oversaw everything (Devroye, n.d.).

To say a bit of Pushpananda Ekanayake’s background in the industry, as he started off his career as a calligraphy creator at the Phoenix advertising agency back in 1981, he has continued his career in the industry as a Sinhala font designer for the Sri Lanka Rupavahini Corporation since 1982. Once the computers were properly introduced to Sri Lanka in the 1990s he and other professionals of the field detected shortcomings and defects in the utilized Sinhala fonts for these computers.

Motivated by this Mr Ekanayake has taken the step of designing a new set of Sinhala fonts for computers in 1994 (Pushpananda Ekanayaka - Sinhala Fonts, n.d.).

Having contributed to many people, especially the Sri Lankan academics and the publishing industry through his contribution for Sinhala typography, he is also an author and educator who tries to share his immense knowledge with the future generations. Through his book Pariganaka Sinhalaya (පරිගණක සිංහලය) he talks about his journey and struggles of merging computer and Sinhala typefaces together, providing answers for many related issues (Sooriya Books, 2021). To continue his contribution for the industry more and more Mr. Ekanayake started an organization named The FontMaster, through which he continues his work, collaboratively with other admirers of Sinhala typefaces and typography. Through this organization he continues to search possibilities of Sinhala typography in unicodes starting from the font MalithiWeb intended for websites (Pushpananda Ekanayaka - Sinhala Fonts, n.d.).

Both Pushpananda Ekanayaka, Microimage and many other entities played a vital role in the early days of Sinhala font digitization. They paved the way for other companies to follow suit, and today, there are many companies in Sri Lanka that specialize in Sinhala font design and production. The digitization of Sinhala fonts has made it easier for designers and publishers to produce high-quality Sinhala language content for a variety of applications, including print and digital media.

2.4.2 Importance of a digital Sinhala font in the current typographic industry

The availability of digital Sinhala fonts has been a game-changer in the modern typographic industry. It has opened up new avenues for typography, making it possible to create high-quality, professional-looking Sinhala content for a variety of applications, including print and digital media.

One of the main advantages of digital Sinhala fonts is that they allow for greater flexibility and customization in typography. With digital fonts, designers can adjust the size, spacing, and other parameters of the font to fit the requirements of different applications. They can also manipulate the font in various ways to create unique and distinctive typography, such as adding special effects or incorporating custom ligatures.

a) Unavailability of optimization for digital Sinhala fonts

Through the recent years Sri Lanka has seen an improvement of digitization in the Sinhala typographic industry. With the increasing varieties of fonts across different styles and variations, the Sinhala typographic industry has come a long way since the first adaptation of a digital font. But the earliest Sinhala typefaces were designed for print purpose therefore the optimum readability required for specific purposes, (in this case small screen digital devices) was not addressed properly. The digitization effort of these typefaces only changed the context they performed in. The original context for these typefaces were print media and the process of digitization did not follow an optimization step. As explained previously, digitally optimized fonts have some special characteristics such as anti-aliasing, hinting etc. which allows them to perform well in a digital context while the digitally converted Sinhala fonts did not have any of these steps for optimization.

One of the main reasons for the lack of optimization can be identified as the lack of literature specific to Sinhala scripts regarding Sinhala letter legibility in the context of digital screens. There has not been any proper scientific studies in the subject of Sinhala font legibility in the context of digital screens. Even though there is sufficient research and literature available for Latin fonts in this topic, adopting research done for Latin type anatomy is not accurate since Sinhala font anatomy can be significantly different. More details on this fact will be discussed in Chapter 03.

b) Potentials of a digitally optimized font

Digital Sinhala fonts have also made it easier for publishers and designers to create Sinhala language content for digital media. With the rise of the internet and digital devices, there has been an increasing demand for Sinhala language content in digital formats. Digital fonts have made it possible to produce high-quality Sinhala content for digital media, such as websites, e-books, and mobile applications.

In addition to their practical advantages, digital Sinhala fonts have also contributed to the preservation and promotion of Sinhala language and culture. By making it easier to create high-quality Sinhala language content, digital fonts have helped to promote the use of the Sinhala language in various contexts. They have also contributed to the development of Sinhala typography as an art form, with designers using digital tools to create innovative and expressive typographic designs.

2.5 Chapter Two Summary

Chapter 2 of this research thesis provides an in-depth overview of the evolution of typography from print media to digital platforms, highlighting the importance of legibility in both contexts. The chapter begins by introducing the basic terminologies of typography and explaining the anatomy of Latin fonts, emphasizing the significance of typography in historical and modern contexts. The chapter then explores the digitization of information and platforms, including differences between digital and print media, types of screens, encoding standards, and operating systems.

The section on digital typefaces and legibility focuses on the need for legible fonts in digital media, especially on small screens. The concept of legibility is defined, and its impact on reading speed and sensory overload is discussed. The chapter emphasizes the factors affecting the legibility of

Latin fonts, highlighting the importance of identifying these factors. The section also provides case studies on how special fonts such as Georgia and Verdana were designed with legibility as the main factor.

Furthermore, the chapter highlights the significance of letter features in legibility and how they impact letter misidentification. The research emphasizes the need to identify core letter features to enhance legibility and to analyze similar letter misidentification from a type design perspective. The chapter discusses test methods for legibility testing, such as distance testing, short exposure method, and parafoveal vision testing.

Moreover, the chapter delves into the digitization of Sinhala typefaces, addressing the problems faced when not using a digitally optimized font in the context of digital platforms where the user has to interact with smaller-sized digital screens. The section discusses the evolution of the Sinhala font industry and its digitization phase, highlighting the importance of an optimized digital Sinhala font in the current typographic industry. The section provides case studies on attempts at digitizing Sinhala fonts and emphasizes the potential of a digitally optimized Sinhala font for small digital screens.

In conclusion, the second chapter of the research provides a comprehensive overview of the development of digital typography and its significance in various contexts, with a special focus on the role of legibility in digital typefaces. The research emphasizes the need for legible fonts on small digital screens, highlighting the significance of letter features in enhancing legibility. The research also fills the gap in Sri Lankan typographic research by discussing the typographic aspect of legibility, focusing on the anatomy of the letterform and its impact on legibility. Moreover, the research emphasizes the rarity of Sinhala legibility research and highlights the importance of digitizing Sinhala typefaces to enhance legibility on digital platforms.

CHAPTER 03: SINHALA ANATOMY AND DIGITAL FONTS

This chapter mainly focuses on how the research was conducted to obtain the necessary samples of the typefaces. In order to understand the process of optimization for the best possible anatomical structure of a letter, a base structure was identified. This base structure was obtained through the identification of the most basic anatomical strokes of the letter. The reason for building up the research based on these basic structures of the letter was that Sinhala fonts carry different anatomical variations across different fonts but their core structure remains a constant. This core structure of the letter was analyzed in order to identify the visual features of Sinhala letters which are distinct to each letter. These visual features act as the main contributing factor in similar letter misidentification which in turn affects the legibility of the Sinhala letter. This chapter focuses on selecting a single sample typeface through a sample selection criteria and a legibility test in order to identify the most legible Sinhala font from a sample size of four commonly used fonts. This selected font was then analyzed for its visual features which acts as the independent variable throughout this research.

3.1 Sinhala Type Anatomy

To conduct this research on Sinhala script, this section defines the Sinhala letters and discusses the Sinhala anatomy. To achieve this, a pilot visual survey was conducted to learn how the anatomical features differ among four digital fonts selected from a sample selection criteria and yet sustain the letter skeleton to be the same. At the end of this section it was understood that anatomical features vary from different Sinhal fonts. Therefore the skeletal structure (atomic feature) should be used for the main study towards understanding DVF and optimizing legibility in a typeface.

The history of typographic research on the Sinhala letter dates only less than a decade back. Currently available research on the anatomy of Sinhala script is conducted only on their basic features (Also considered as 'the skeletal structure' which will be explained later in this section). When considering advanced research on typography, other scripts; (mostly western) have a larger research base on the anatomy of their relevant scripts which are based on that corresponding font. Since the lack of research on anatomic features, this section aims to investigate the existing knowledge on the basic structure of Sinhala letter in comparison with its anatomic properties.

A letter is made of strokes with a combination of different types of joints, intersections and terminals; described as the skeleton of the letter. Dalvi and Samarawickrama define the skeleton as stroke primitives as they contain the 'atomic features' of a letter that depicts the most appropriate set of strokes that makes a letter (specific to writing a letter). The term 'atomic' is derived from 'atom' which is considered the basic structural component of an element. This atomic structure is the skeleton of the letter which the anatomical features are built upon. Even though the terms 'atomic' and 'anatomic' were used in similar conjunction, these terms are NOT considered as antonyms of each other. The skeletal structure can be considered as the baseline observation viewpoints when analyzing the structural composition of a letter. This structure of a letter is observed in a micro viewpoint and these stroke primitives are based on how the letter is composed with its strokes, joints and intersections at a basic level.

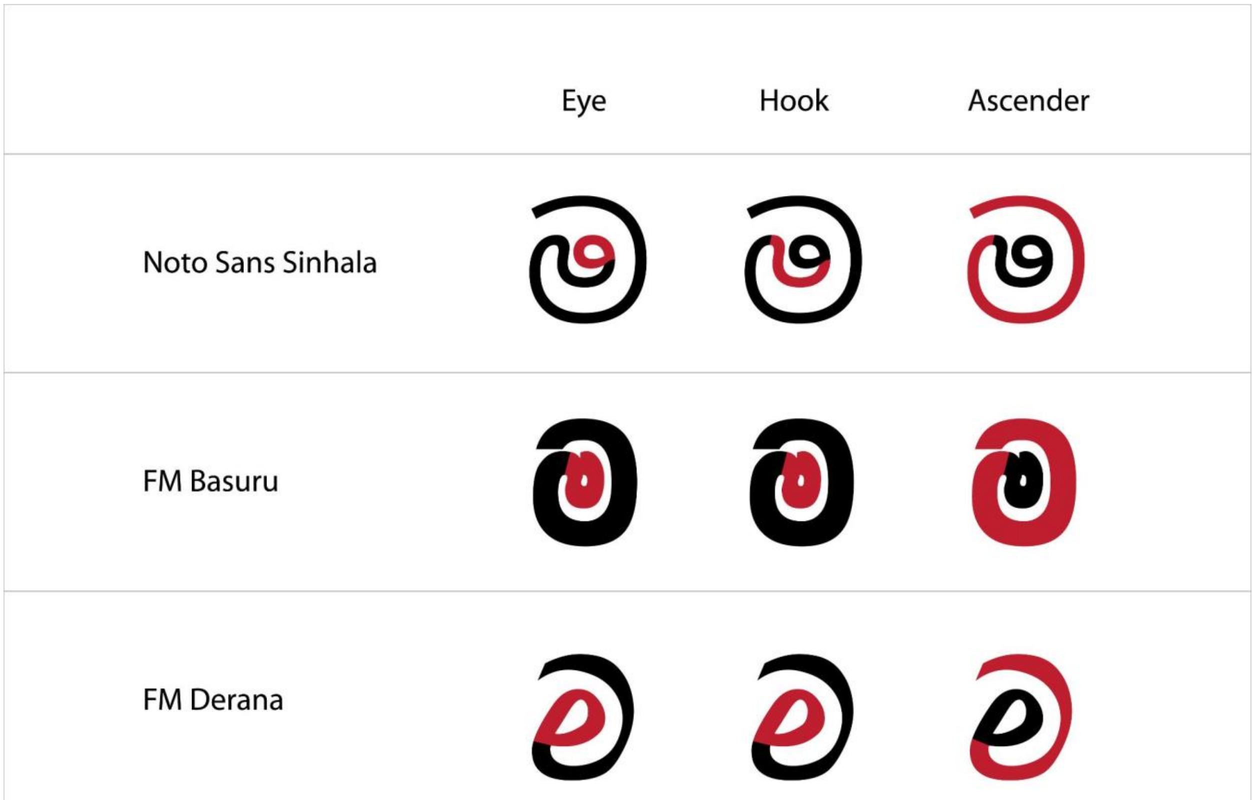


Figure 6: Differences in anatomical properties across different fonts of the same letter

The skeletal structure helps to identify the distinct visual properties of a specific letter. In comparison to the skeletal structure, anatomic features are observed at a more macro level. It is defined as the ‘composite strokes of a letter’ rather than its skeletons' ‘primitive strokes’. Anatomic features are the variables that are used in the current typographic research in order to identify and classify typographic elements in this field. Both skeleton and anatomic features (stroke primitives and composite strokes) can be examined through a methodical visual survey to gain insight on the distinct visual properties of each letter and to identify the most appropriate features when designing a font.

This chapter aims to investigate the stroke differences between the skeleton and anatomic features, followed by a visual survey on the visual variations of anatomic features of selected fonts. The chapter comprises two researches conducted to understand different stages: first stage investigates the skeletal and the anatomic stroke application to letters. The second stage examines the distinct visual features of fonts which are derived from the skeletal structure. The visual survey includes 12 fonts that range from mono-linear to modulated selected from a sample selection criteria which encompasses fonts used for both print and digital usage. A set of 26 selected letters were individually analyzed on a visual criterion based on the 19 skeletal properties defined in early research on atomic properties by Samarawickrama. The data was tabled and marked separately to be included in the analysis.

3.1.1 Defining type anatomy through the skeletal structure

The concept of understanding the anatomy of type is believed to have originated in Latin scripts due to its long history of print traditions. It describes the graphical elements that make up a typeface. This includes its base strokes in combination with joints, intersections and terminals which can be identified as the skeleton of the letter. But even though the structure of a font is described by the anatomy, a more microscopic level could be analyzed when studying the basic structure of letterforms. Dalvi and Samarawickrama define this primal skeletal structure as ‘stroke primitives’ as they contain the ‘atomic structure’ of a letter that defines the most ideal set of strokes that makes a letter (ideal letter).

The current knowledge of Sri Lankan typography is based on the skeletal properties. In order to contribute to the future of typographic education, this is insufficient since the anatomical identifications of typography should be defined. Therefore, this chapter aims to investigate the current knowledge of skeletal properties in comparison with the required knowledge of anatomical properties which can be found in the Sinhala fonts that are widely used in Sri Lanka. This knowledge will provide a foundation for the analysis of Sinhala fonts for this whole research.

In the process of trying to identify the anatomical properties of a letter, three aspects must be considered; which are the hand, the tool and the proportions (Dalvi, 2010). In this chapter, only two aspects will be discussed; the hand and the tool used. The third aspect of proportions will be discussed in a separate chapter because of its influence on legibility on small font sizes. Samarawickrama has stated that there are 19 distinct visual features in Sinhala letters with 33 sub features (Annex 01). The priority of this chapter is about defining the anatomic features of Sinhala letterforms with skeletal features as the base. In order to achieve this, these 19 features will be used as the base theory where this research is built upon.

3.1.2 Distinct Visual Features of a Sinhala letter

Sinhala font anatomy can be understood by analyzing the root letter (skeletal structure) of the letter. These root letters are made up of stroke primitives which define the basic shape of the letter. (Samarawickrama, 2016) Distinct Visual Features are the terminology given to letter features which can be found common between all Sinhala letters. These visual properties in the root letter combine together to form the skeletal structure of the letter and these visual properties can be used to identify, analyze and segregate parts of the letter same as identifying the anatomy of Latin fonts. There are a total of 19 DVF in Sinhala with additional 33 sub features. DVF are used as a basic nomenclature method to identify parts of a letter instead of using anatomical features. Using DVF alleviates the problem of having vastly varying anatomical differences between fonts in Sinhala scripts.

3.2 Defining the independent variable of the visual analysis

The research is done in three stages. First a set of 12 Sinhala fonts were selected through a selection criteria which are widely used in Sri Lanka. Then the anatomic features of these fonts were compared with the 19 skeletal features present on an ideal letter as described by Samarawickrama (Annex 01). This would allow defining the anatomic features based on the individual font's variations from its skeletal features. The final part is to analyze the fonts in cross reference to each other based on the tool and hand techniques through the process of superimposition. After these three stages of analysis, a conclusion could be made regarding the anatomic properties of selected Sinhala fonts.

3.2.1 Sample selection criteria of 12 fonts

A sample group of 12 fonts were selected based on a criteria. The requirements were based on a few factors:

- The fonts must be widely used by the public in the country
- Must cover the usage across different platforms like android, iOS, Windows, Mac etc.
- Must cover the usage across various devices such as PC, laptops and mobile devices
- Must be used on both print and digital media
- Must contain stroke types both monolinear and modulated

With the above factors being considered, a set of 12 fonts were selected which was used most commonly in both printed and digital media.

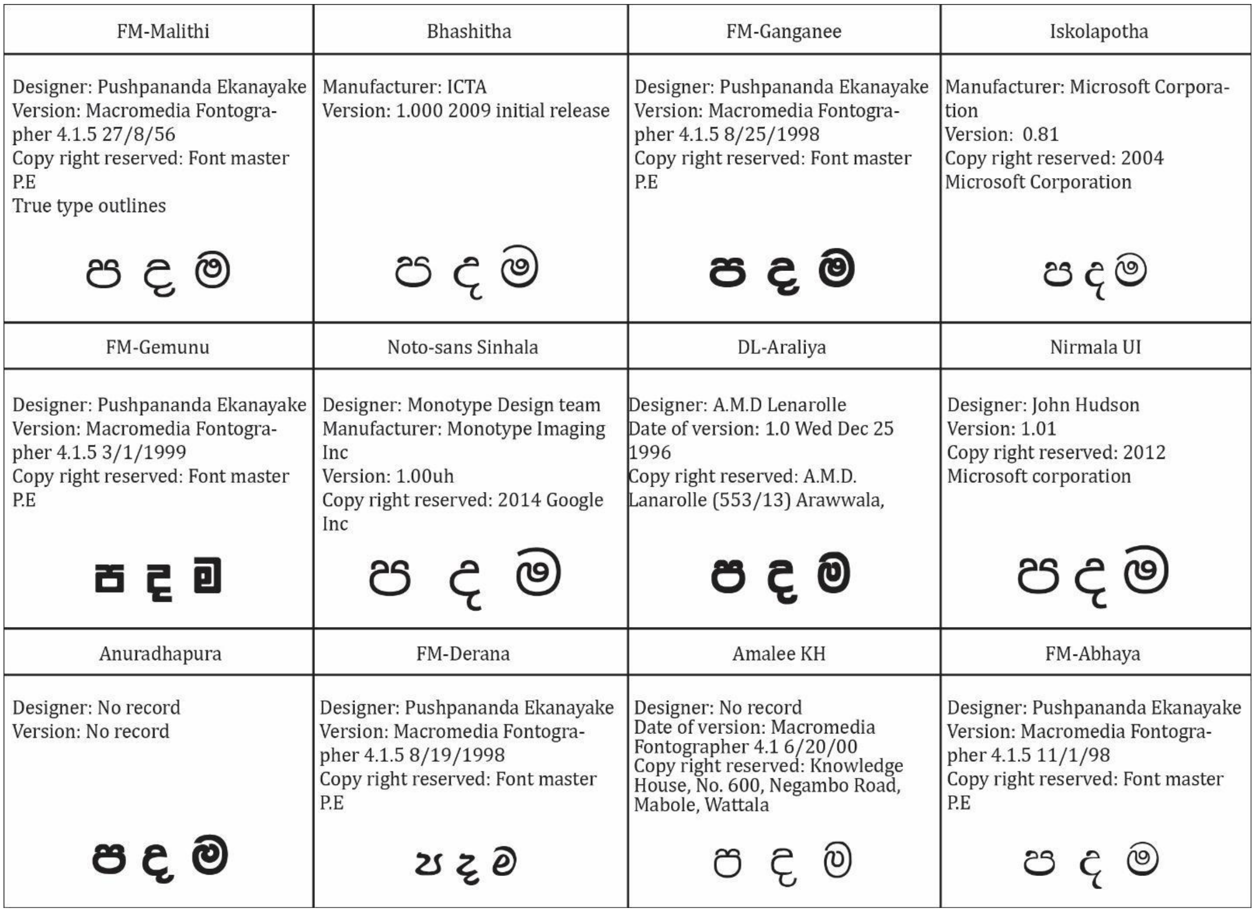


Figure 7: The selected sample set of 12 fonts for the analysis

In order for the anatomic properties to be analyzed for the above selected fonts, their typographical features should be compared with the skeletal structure (stroke primitives) identified by Samarawickrama. These 19 skeletal properties including their 33 sub characters were analyzed one by one across each font to define its anatomical variations.

3.2.2 Selecting the ideal letter set for DV feature comparisons

Defining each and every letter is a complex task since the Sinhala language has a total of 60 letters (18 vowels and 42 consonants) not including the modifiers (diacritics) added to them. In order to overcome this problem, a set of 14 letters were selected which covers all the 19 atomic properties collectively. During the process of analyzing these 14 letters across all the 12 fonts, these 19 atomic features (including the 33 subatomic features) can be compared. (Samarawickrama, 2016) (Dalvi, 2010)

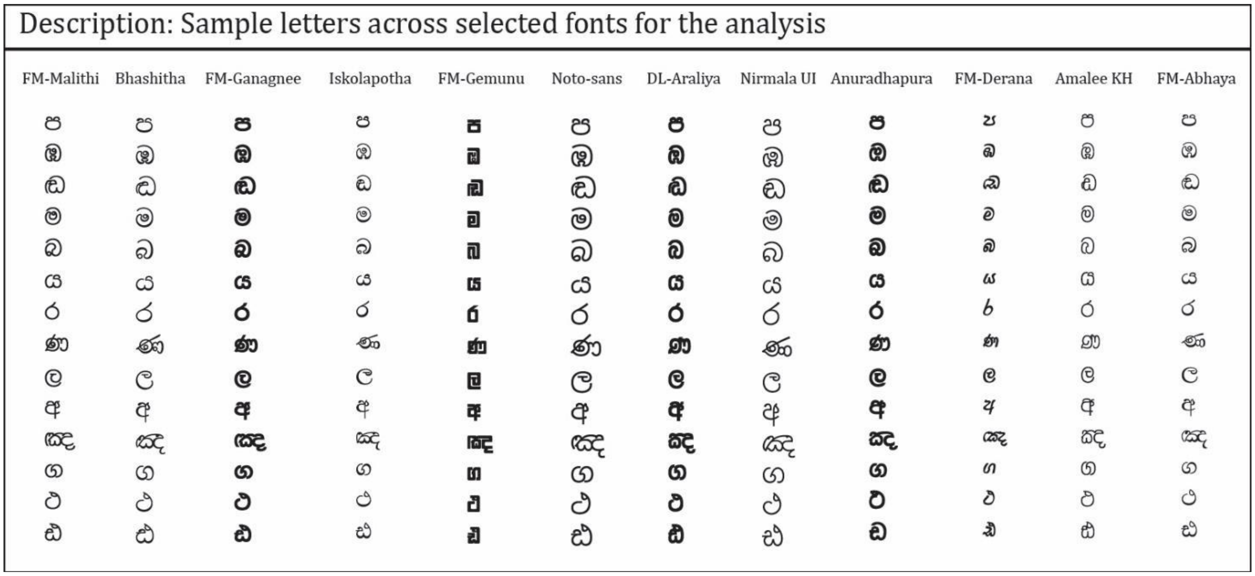


Figure 8 : The set of sample letters from 12 fonts selected for the analysis

3.2.3 Findings on the DV features of Sinhala letters and anatomy of selected fonts

Analyzing the anatomic features of selected letters revealed that there were many variations with the skeletal structure of the ideal letter. This also extended to having drastic differences among the selected fonts too. Below examples show some of these variations when compared.

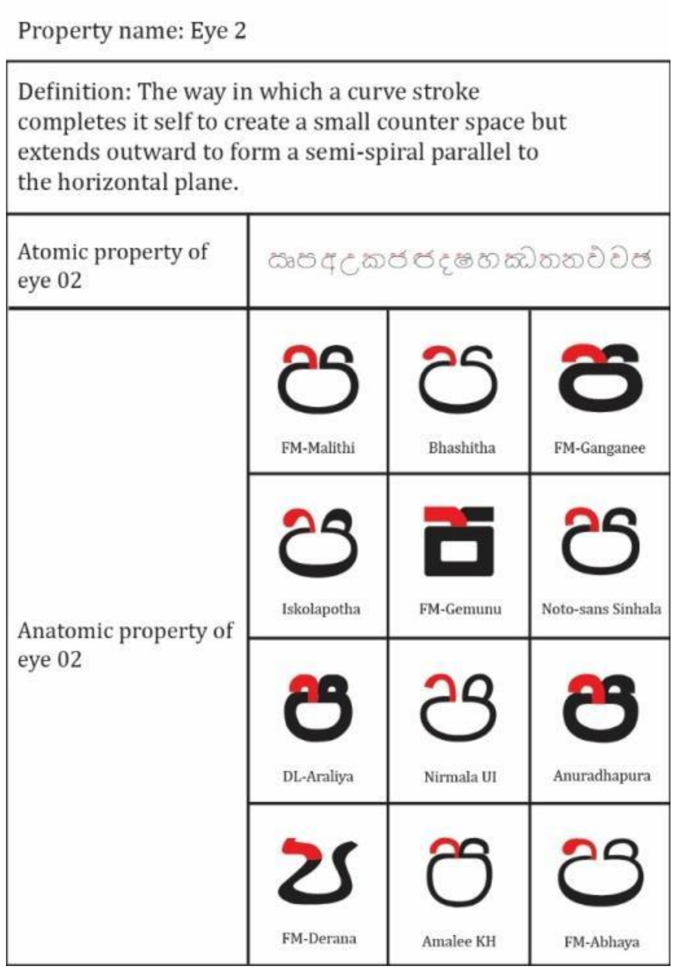


Figure 9: DV feature of the letter Pa compared across different fonts

As the definition suggests in the above, the description of the skeletal property Eye 02 does correlate with the actual anatomy of the 12 fonts selected. The curved stroke does not extend outwards to create a small semi spiral parallel to the horizontal plane in any of these fonts. But in some cases like in the fonts DL-Araliya and Anuradhapura, it does create a small counter space on the base stroke. But still this feature can be considered as a drastic variation from the ideal skeletal features. The only factor of ideal feature these fonts have is the curved stroke ending upwards in a curl and creating a counter which only occurs in some of the cases.

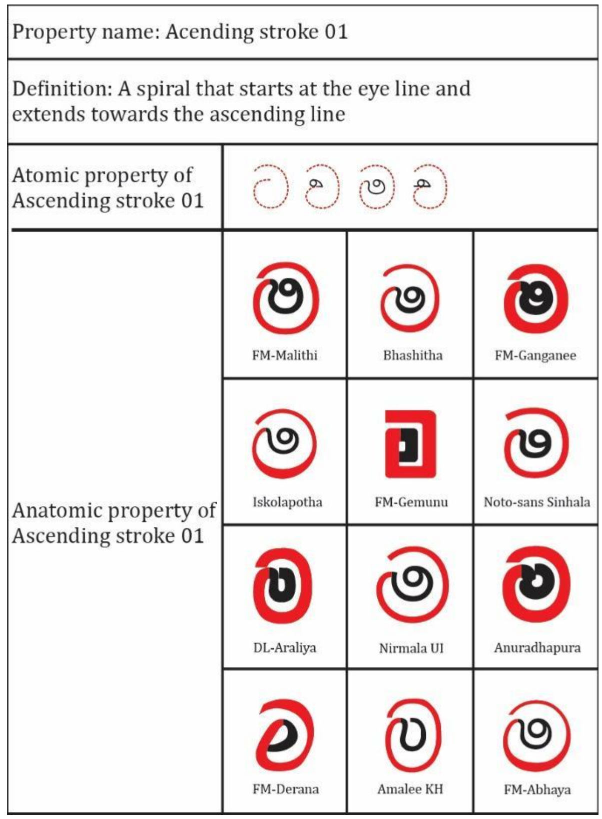
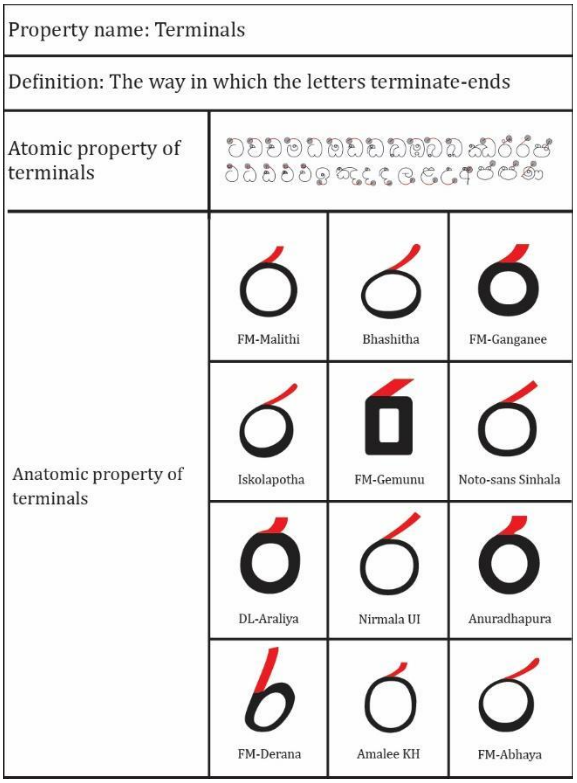


Figure 10: DV feature of the letter Ma compared across different fonts

The letter 'ම(Ma)' in the figure above shows different variations with the ideal letter. In this case, the feature of the Ascending stroke 01 (which was picked from the set of skeletal features present in the ideal letter) is analyzed. The Ascending stroke 01 is defined as a spiral that starts at the eyeline and extends towards the ascending line. But when compared, it was shown that this was not the case in every scenario. The stroke didn't always start at the eyeline and their proportions varied drastically with each font used. This feature was different not only in the above letter (Ma) but across most of the letters within the selected set of 12 fonts.

The terminals describe how a letter terminates at the end of its strokes. Every Sinhala letter has a terminal which makes the variations among these letters rather complex. In the analyzed 12 font samples, the directions of the terminations vary with vertical, horizontal or diagonal alignments. As shown in the below diagram, the shape of the tip of the terminal also varies. It takes flat, rounded or oblique shapes. In the letter 'ර(Ra)' as shown in the figure below, all of the mentioned variations could be seen.



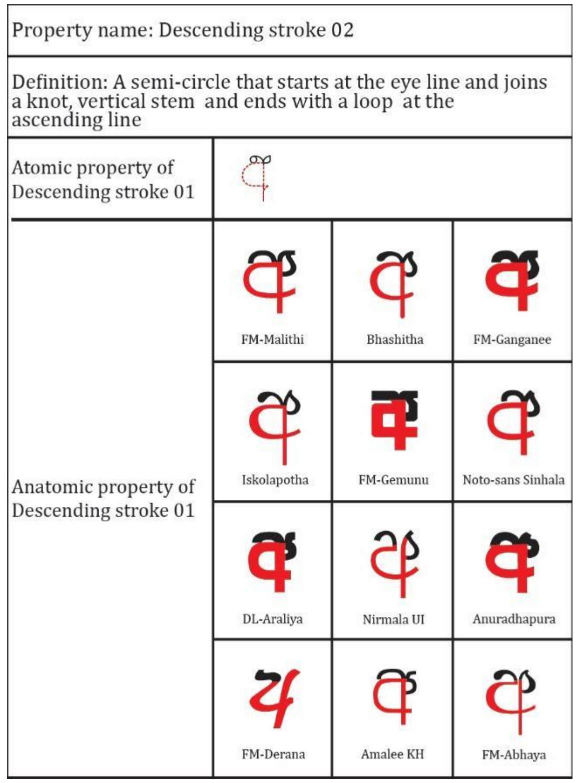


Figure 11: DV feature of the letter Ra compared across different fonts (Left)
Figure 12: DV feature of the letter Aa compared across different fonts (Right)

The letter 'ඇ (aa)' is another letter which has so many variations from the ideal skeletal structure. It shows variations on the descending stroke and the knot that is formed at the lower part of the base descender is not present in any of the 12 fonts selected. The knot is transformed into a joint instead. Also, the stem that touches the eyeline on the top of the letter has a lot of variations of loops present across. This letter can be taken as a good example to showcase how the ideal letterform undergoes changes when it comes to defining the anatomy of commonly used fonts.

The curve to curve joint is a DVF which shows similarities in the skeletal structure but yet variations in its anatomic form. When the below diagram is considered, across all the 12 fonts, the bottom two curves of the letter 'ය (Ya)' is joined together to form a curve to curve joint just as the ideal letter. But the angles of connection, space created in between the curves and the height of the joint varies. This shows how the anatomical features can define the uniqueness of a letter even though their skeletal structure remains the same.

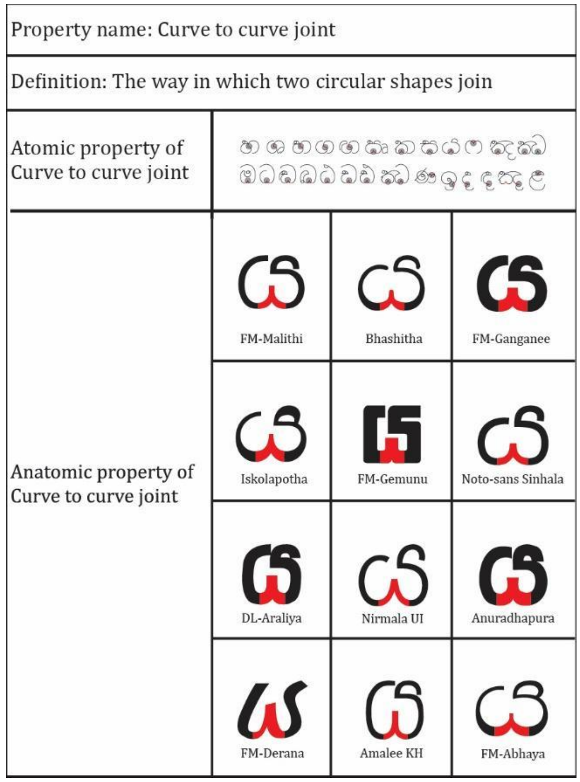


Figure 13: DV feature of the letter Ya compared across different fonts

3.2.4 Conclusion from the findings

These findings analyze the 12 commonly used Sinhala fonts to identify variations from the ideal skeletal structure of Sinhala letters. The aim of the analysis is to understand how the anatomical features of Sinhala letters contribute to legibility on small digital device screens.

First section focuses on the feature Eye 02, which is defined as a curved stroke that extends outwards to create a small semi-spiral parallel to the horizontal plane. The analysis shows that none of the 12 fonts selected exhibit this feature in its ideal form. While some fonts like DL-Araliya and Anuradhapura create a small counter space on the base stroke, this feature can be considered a drastic variation from the ideal skeletal features. The letter 'ම' is then used as an example to illustrate the variations in the Ascending Stroke 01, which is defined as a spiral that starts at the eyeline and extends towards the ascending line. The analysis shows that the stroke does not always start at the eyeline and the proportions vary drastically across fonts.

Next, the findings discuss the variations in terminals, which describe how a letter terminates at the end of its strokes. The analysis shows that the directions of the terminations vary with vertical, horizontal, or diagonal alignments. The shape of the tip of the terminal also varies, taking flat, rounded, or oblique shapes. The letter 'ර' is used as an example to illustrate all the variations in terminals.

The letter 'ඥ' is used as another example to showcase how the ideal letterform undergoes changes when defining the anatomy of commonly used fonts. The analysis shows that the knot formed at the lower part of the base descender is not present in any of the 12 fonts selected, and the stem that touches the eyeline on the top of the letter has a lot of variations of loops present across.

Finally, the Curve to Curve Joint is analyzed to show how the anatomical features can define the uniqueness of a letter even though their skeletal structure remains the same. The analysis shows that across all the 12 fonts, the bottom two curves of the letter 'ශ' are joined together to form a curve to curve joint just as the ideal letter, but the angles of connection, space created in between the curves, and the height of the joint varies.

In conclusion, the analysis of the 12 Sinhala fonts highlights the significant variations in their anatomical features from the ideal skeletal structure of Sinhala letters. These variations contribute to the legibility of Sinhala fonts on small digital device screens and need to be taken into consideration when optimizing Sinhala typeface features for better legibility.

3.3 Defining the dependant variable for the visual analysis

DVF of Sinhala letters are made up of primitive strokes, yet the anatomy of a letter is considered to be composed of composite strokes. (Dalvi, 2010) In order to understand anatomy of the Sinhala letter, a proper classification is needed. Sinhala typographic knowledge lacks the required theoretical applications to classify Sinhala fonts according to their anatomy. Even though Latin typefaces have a plethora of classification schemes, these classification theories become inapplicable in the local context due to the morphological differences present in the South Asian type anatomy. (Dalvi, 2010) Girish Dalvi suggests a model based on the structure and the appearance of the letter to classify Devanagari scripts into 4 separate categories. This model can also be used to categorize Sinhala letterforms according to their anatomical differences. (Samarawickrama, 2016)

3.3.1 Hand and tool

The three factors hand, tool and proportions are essential elements that have to be considered when identifying topographic features. Even though the trio hand, tool and proportion cannot be defined as one of the distinct visual features of Sinhala letters, it still must be considered in order to completely understand the anatomical features of Sinhala scripts. But in this research, only two factors, the hand and the tool were analyzed since analyzing proportions requires much extensive research and a solid background literature; which Sri Lankan typographic education does not have yet. So the proportions were kept as constants in the process of analysis. The proportions were based on the point size of the letter and not the baseline to ascender height (x height). Further details on adjusting x-height for a proper analysis is discussed in the section 3.6

The tool can be defined as the instrument used to draw the type. (Dalvi, 2010) The usage of different tools defines the unique characters of strokes of the letters. Tools such as the roman pen, flat brush, copper nib pen and monolinear pen/stylus are used to bring about the tool variations. From the 12 fonts selected, the evident tools which could be related was the monolinear pen and the copper nib pen which draws strokes in the same thickness and uniformly varying thickness respectively. Only one font (FM Derana) was identified as a font which used a brush pen.

Property name: Tool	
Definition: Instrument such as the pen, which is used to draw type. The commonly used tools are copper nibs, mono-linear pen/ sty lus, brushes. (The tools used to draw the letter in the give typefaces)	
Mono-linear pen	FM-Malithi, FM-Ganganee, FM-Gemunu, Noto-sans Sinhala, DL-Araliya, Nirmala UI, Anuradhapura, Amalee KH
Roman pen	Bhashitha, Iskolapotha, FM-Abhaya
Brush	FM-Derana

Figure 14: Identification by tool as a typographic feature. Above table shows the letter 'Pa' drawn with different tools

Even though the consistency of the stroke is determined by the tool, the movement of the hand governs the motion of the tool. It brings about a stroke-contrast variation through angle, rotation and the pressure of the hand. There are several classification methods present in typographical studies which are based on the above factor. But the most commonly used classification, the Vox classification, is considered in this research to categorize the type based on the usage of the hand.

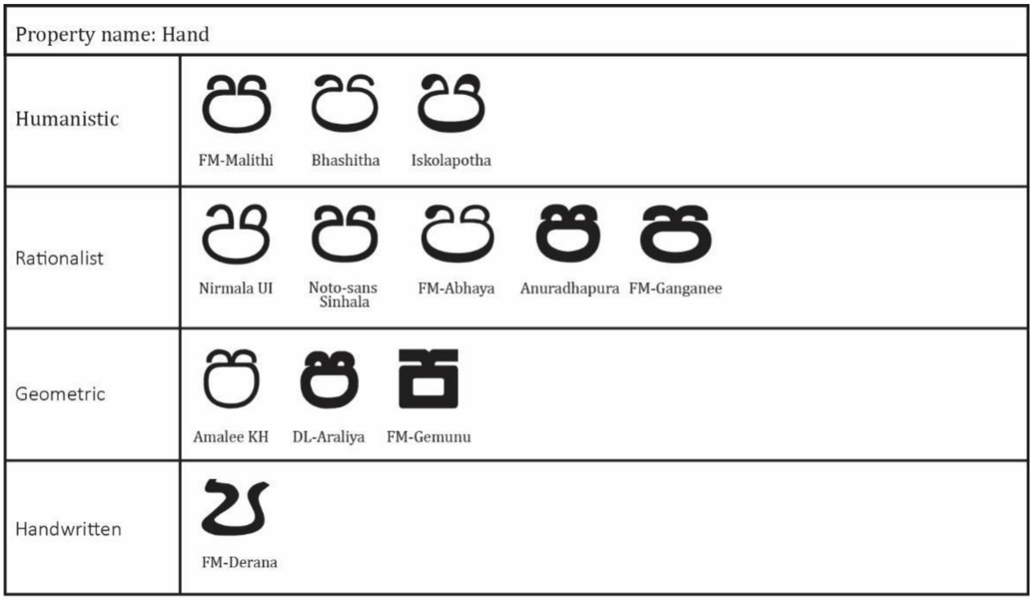


Figure 15: Identification by hand as a typographic feature. Above table shows the letter 'Pa' drawn with different hands

When visually analyzed, similarities to Vox Classification for Latin types can be seen in Sinhala letterforms too. Even though more detailed research must be conducted in this subject to theoretically categorize Sinhala letterforms into groups according to their usage of Hand and Tool, a visual analysis is sufficient to get a superficial understanding on the subject. The Vox Classification can be described as follows:

Handwritten:
The strokes are less regular with perfect and optimized geometric shapes of a letter. This style can be identified as the closest to natural handwriting and shows drastic variations with the tool usage.

Humanist:
This style displays a similar visual style to handwritten strokes but with some consistent and strict strokes. This style is considered to have the greatest number of features similar to the atomic properties of an ideal letter.

Rationalist:
This style shows drastic deviation from the ideal letterforms to achieve a more rational approach. These font types are optically corrected for optimized viewing through print and digital media.

Geometric:
Geometric style typefaces have consistent strokes with geometric shapes. Since Sinhala is always a geometric script, its derivatives naturally tend to become geometric fonts.

3.3.2 Flesh and gray value

The flesh of a typeface can be identified as the stroke boundaries that make the typeface (Samarawickrama, 2016). When defining the flesh, the construct of the stoke is considered. Some typefaces have incomplete flesh in their strokes with dotted or discontinuous lines. But in this research, all the 12 fonts selected had a solid build and hence variations in the flesh do not occur. The feature of flesh is not defined by the skeletal features since skeletal features only derive from primitive strokes rather than composite strokes. The flesh is a factor present in composite stroke.

Even though the flesh is all the same, the gray value isn't. The gray value is described by the amount of blackness or the overall darkness across a letter. It can be categorized as light, normal, semi-bold, bold etc. In the selected sample set of 12 fonts, different variations of gray values could be seen across the letters ranging from low to high. The lowest gray value could be seen in FM-Abhaya and the highest in FM-Gemunu.

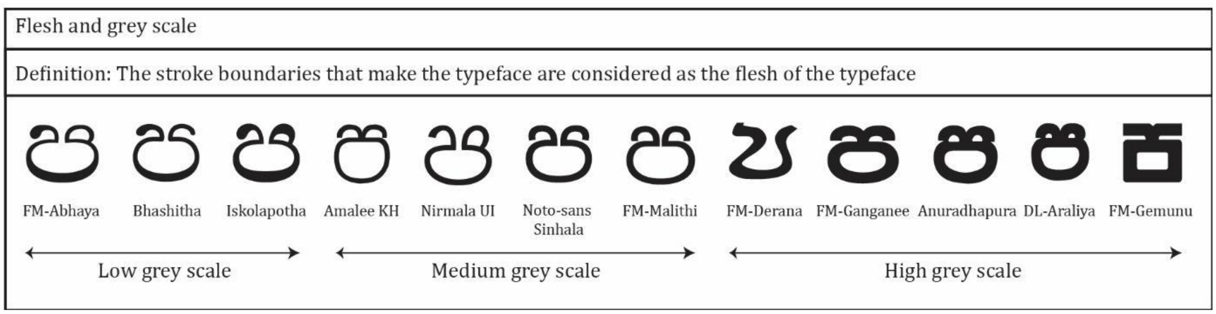


Figure 16: A spectrum of different gray values across different fonts of the letter 'Pa'

3.3.3 Contrast and axis

The contrast of a letter can be identified as the thickness or the thinness of a stroke. It's a result generated by hand and tool variations when constructing the letter. Contrast can be generally categorized into no contrast, low contrast, mid contrast and high contrast letters. (Dalvi, 2010) But in the selected font samples, high contrast letters could not be seen. The letters without a contrast are considered to be monolinear letters (eg; Noto Sans Sinhala) while others can be categorized into low and mid contrast letters based on the differences between thickness and the thinness of the stroke. High contrast letters in Sinhala show similar anatomical features to modulated letters in Latin. Even though there is not enough literature to categorize Sinhala letters as monolinear and modulated, analysis of the data gathered from this visual survey showed that the contrast of Latin and Sinhala fonts follow similar guidelines.

By understanding the orientation of the axis (stress) of a letter, the distribution of contrast can be identified. Axis is the straight line through the thinnest part of the stroke, and it conveys the direction in which a curved stroke changes its direction while changing in weight. (Samarawickrama, 2016) This axis depends on the tool or/and the hand technique used.

Monolinear fonts do not have an axis (denoted by vertical axis below to show symmetry) since they do not carry thick and thin strokes.

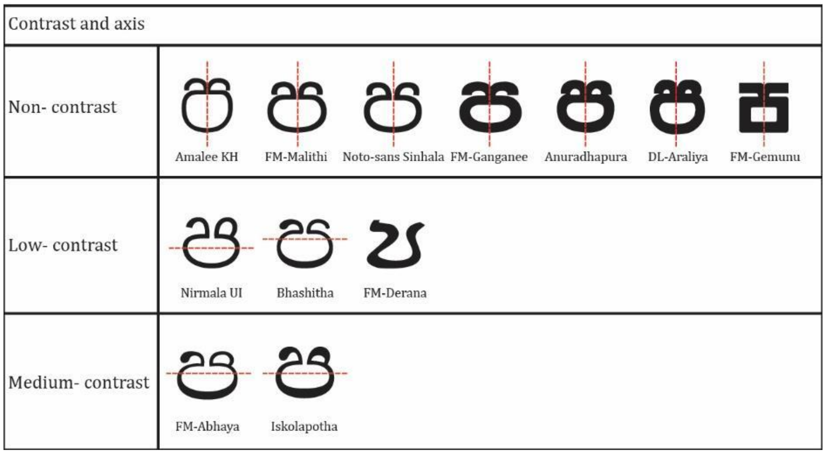


Figure 17: Different contrasts and axes of the letter 'Pa' in different fonts

3.4 Visual analysis of sinhala digital fonts

With the identification of skeletal features and selection of 12 commonly used fonts, we were able to identify the anatomic features of Sinhala letters. Even though the anatomic features present in a letter shared similarities within the letters in the same font, it was also found that there were no static anatomic features which are common across all fonts. But still the skeletal features were considered to be common between letters and some can be seen across different font variations in pure form or as some derivatives. The absence of static anatomic properties in Sinhala letters makes them considerably different from Latin letters. This leads to the problem of using previous research and case studies done for Latin letters inaccurate when used as an analysis for Sinhala letters. The below figures show how some of the unique anatomical features are represented in three of the selected fonts. These unique features were derived from the skeletal properties but yet they show differences in nature when their anatomic considerations are taken into account.

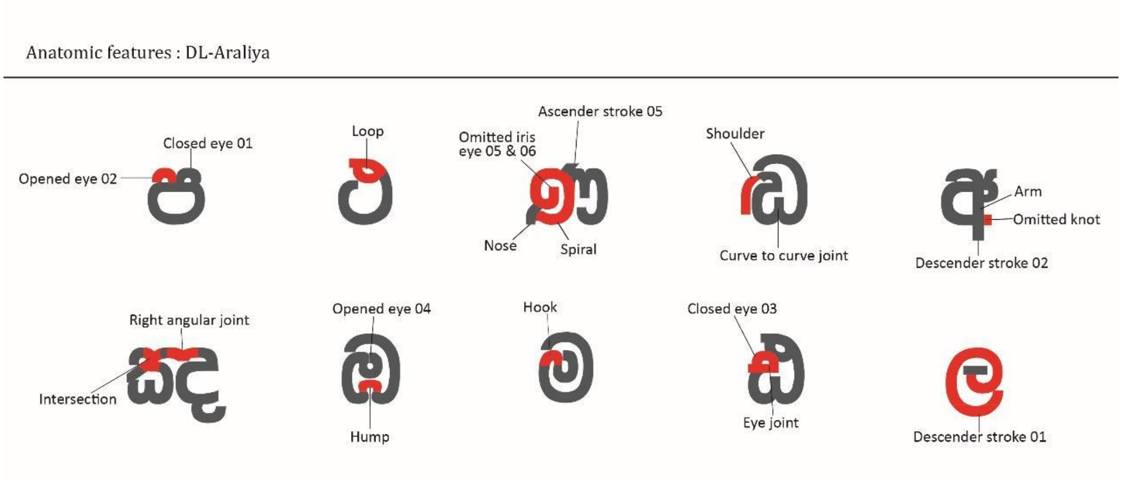


Figure 18: The font 'DL-Araliya and its anatomical features.

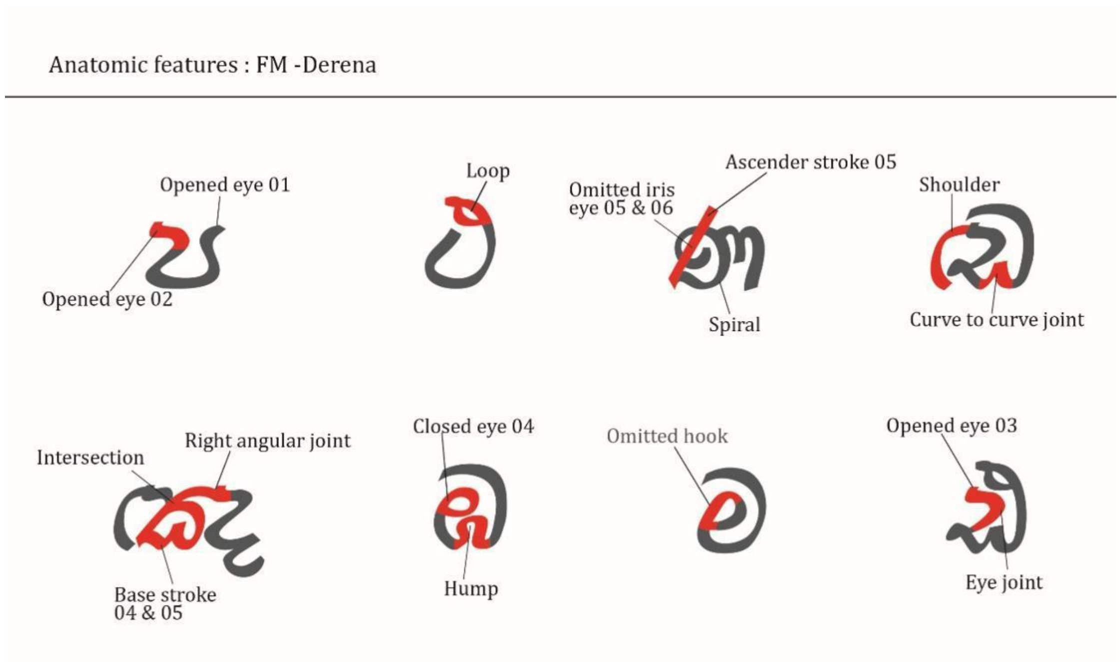


Figure 19: The font 'FM-Derana' and its anatomical features.

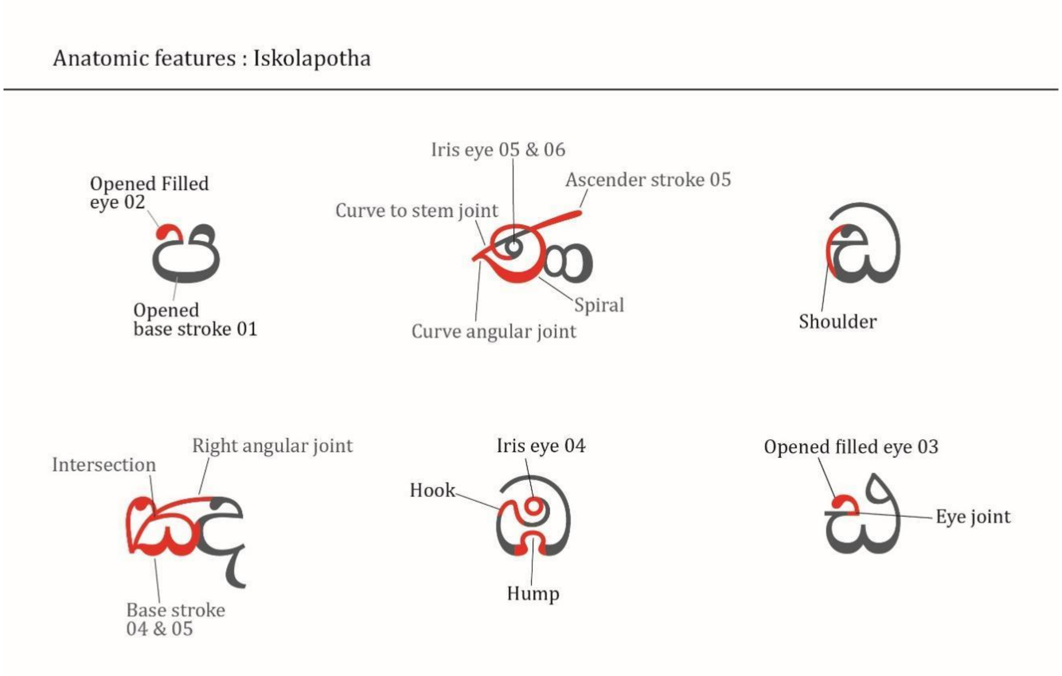


Figure 20: The font 'Iskoola Pota' and its anatomical features.

When taking an example to prove the above point, two of the above fonts DL-Araliya and Iskoolapotha has a 'hook' in the letter 'ම (Ma)' while the font FM-Derana has the hook omitted in the same letter. Same thing happens in the letter 'ණ (Na)' where Iskoolapotha has the feature Iris eye 05 & 06 while the other two fonts don't. Another special feature of this letter 'Na' is that in the font DL-Araliya, the feature Ascender stroke 05 is discontinuous. In all the other fonts, this ascender stroke can be seen as a straight line which is uninterrupted. But in this DL-Araliya font, the stroke stops at the start of the spiral and begins again at the top of the spiral.

The stages of the research proved that the ideal skeletal properties don't always coincide with the anatomic properties with the fonts that are in contemporary use. These anatomical features were altered according to the context of their use and preferences. Manly for esthetic purposes and font personality. The rationale of the altercations will be explained in future chapters in this research and can be done in order to further understand the behavior of Sinhala anatomy in the modern contexts such as its usage in small scale digital interfaces.

3.4.1 Potential for using Distinct Visual Features for legibility testing in Sinhala letters

As mentioned earlier in this chapter, anatomical features unique to each and every font can affect the visual clarity when viewed under certain conditions. (Grant, 1916) Therefore the anatomical features identified in the above Sinhala typefaces can also have an effect on the legibility of the font. But the issue with this relationship is that, as discussed earlier in this chapter, anatomical features are inconsistent when it comes to Sinhala fonts. Hence this chapter focused on establishing the relationship between Distinct Visual Features in the skeletal structure and anatomical variations. By exploring this relationship, the connection between legibility and DVF can be identified. This behavior can be further investigated to understand the relationship between anatomy and legibility of a letter. Though the phenomena known as similar letter misidentification, impact of DVF on the legibility of the letter can be visually analyzed. This experiment is carried out in the next chapter where each anatomically different Sinhala font is examined in small digital screen sizes to assess their performance.

3.5 Defining sinhala anatomy for small screens

Since similar letter misidentification is one of the key factors which affect the legibility of a typeface, understanding the anatomy of the Sinhala letter which leads to letter misidentification between letters is crucial. It occurs in a font where two anatomically similar letters are misinterpreted as one or the other. Recognizing the distinct visual features leads to understanding these anatomical differences but since Sinhala anatomy varies drastically across various fonts, a single font must be selected in order to do a visual survey on Similar Letter Misidentification (SLM). This font is selected from a simple legibility test with a sample size of 4 fonts which was picked according to a selection criteria based on their usage.

3.5.1 Problems in defining legibility for Sinhala typefaces

Legibility of a character can be affected by several factors. Among them, character resemblance and size of the letters are the most crucial factors that increase or decrease the legibility of a particular font. (Larson, 2010) Character resemblance and size of the letter are also interdependent on each other. In other words, the tendency for a smaller sized character to be misidentified as another character of similar skeletal structure is higher than a larger sized character. In Latin fonts, the main factor that affects this SLM is the anatomy of the letter (Beier, 2009)

Compared to the amount of research done for Latin fonts in this field, there is a considerable void in Sinhala typeface research targeted for legibility. As mentioned previously, the main problem with analyzing Sinhala letters for legibility is its inconsistency with anatomy. Since the skeletal structure of the Sinhala letter is consistent, defining the anatomy of Sinhalal letters through its DFV in the skeletal structure is a necessity in order to alleviate this problem. To understand these features properly, tests were done on one selected font from a sample set of 4 fonts. So choosing a Sinhala font with a high default legibility in small digital device screens was crucial for this research.

3.5.2 Selection criteria for Sinhala typefaces in measuring legibility

Four different fonts were selected according to criteria which would address the context specific needs. It was based basically on a fonts' digital presence. The fonts needed to be Unicode and used on different platforms in the context of Sinhala digital displays. No display specialized fonts were selected because this research is based on the legibility of body fonts.

a) Selecting sample fonts to test legibility based on purpose

i. Multi-platform usage

The font selection must be across several platforms. Sample sets of popular fonts were selected from Windows, Mac and Linux based operating systems from PC. Operating systems iOS and Android based fonts were selected from mobile devices.

ii. Primary usage as a body font

This was the most important factor that had to be considered since this research is mainly focused on legibility. Display fonts are not used when it comes to displaying a large amount of text in a confined area. Also, since body fonts are normally small (12tp – 8pt) the legibility of the letters in smaller sizes can be observed clearly.

iii. Anatomical diversity

When closely observed, most of the Sinhala fonts existing today are derivatives from an existing font with some minor changes. The lack of anatomical diversity made comparative observation of these types of fonts not worth the effort. Hence, fonts with unique anatomies or the root fonts which these derived fonts have taken inspiration from were used for the selection criteria.

iv. Unicode fonts

Only Unicode fonts have been selected in this research to maintain consistency with the glyphs and the system of ligatures. Sinhala script has a wide variety of ligature fonts and vowel signs that change with the consonant it is used. Unicode fonts have addressed this issue successfully by having a separate encoding for each combination. This protects the consistency and it becomes easier to compare between different sets of typefaces.

b) Font selection for legibility testing

After narrowing down from a pool of 12 different typefaces analyzed in the section 3.1.4, a total set of 4 fonts were selected for a legibility comparison.

i. Noto Sans Sinhala

This font was developed by Google for their Noto Sans collection of a wide variety of fonts. Basically, used on android based platforms and optimized to be used on smaller screens like mobile phones. Noto Sans Sinhala was designed to share its anatomical similarities with its other Noto Sans counterparts.

ii. Nirmala UI

Developed by Microsoft, this font is known to be like its Latin counterpart, Verdana. Designed and developed specifically for on screen displays, Nirmala UI is a widely used font in Microsoft platforms.

iii. Iskoola Potha

Iskoola Pota was one of the first developed Unicode fonts in Sri Lanka. Now used as a body font in most of the online Sinhala content including News sites, this font can be found everywhere not only restricted to digital displays. Since the print industry is also digitized at this point, it is widely used due to its popularity and its ease of use for the reason of being a Unicode font.

iv. Bhashitha Complex

This font was one of the most recently developed fonts by the Information and Communication Technology Agency (ICTA) of Sri Lanka. It has a wider support on almost all the Sinhala based platforms used on web today and most of the government official sites use this font as their basic body font.

3.6 Comparing features that differ between Latin and Sinhala fonts

Most of the fundamental literature based on anatomy and legibility of letters is based on Latin fonts. This can be an issue in cases like considering the optical height of a letter. In most case studies the optical height of fonts were disregarded and x heights were not adjusted. (Beier, 2009) Since this research is based on fonts used in digital screens, the usage of the digital fonts are tied to the point size of the font. This can cause fonts with a bigger x height taking up more screen space than a font with a smaller x height but having the same point size.

3.6.1 Effect of letter height on legibility

Optical size is considered one of the most important factors which affects legibility among other factors such as Gridlines, Stroke Width and Weight, Proportion and Structure. (Kumar, 2017) But Optical height is one of the most overlooked parameters in typographic research since optical height changes with the x height of the letter. This becomes a really important point when comparing different fonts in legibility since different fonts have different x heights according to their anatomical structure. But in most cases this factor was ignored due to technical limitations or ignorance. (Beier, 2009) But in this research, keeping the x height becomes a crucial factor since some visual analysis experiments are based on the method of superimposition.

a) Comparison on Latin 'x-height' and Sinhala 'Pa- height'

The four fonts were tested out in proportionate sizes so that its respective "ප" heights (x height for Latin scripts) would be similar. The reason for this is that Sinhala fonts have a large variation in x heights across different fonts and testing out the legibility on the same point size will not be logical. For this experiment, the letters must be scaled to the same 'maximum height' and magnified rather than their respective point sizes. The maximum height in this case is the height from lowest point of the base stroke to the highest point of the ascending stroke of the biggest letter.

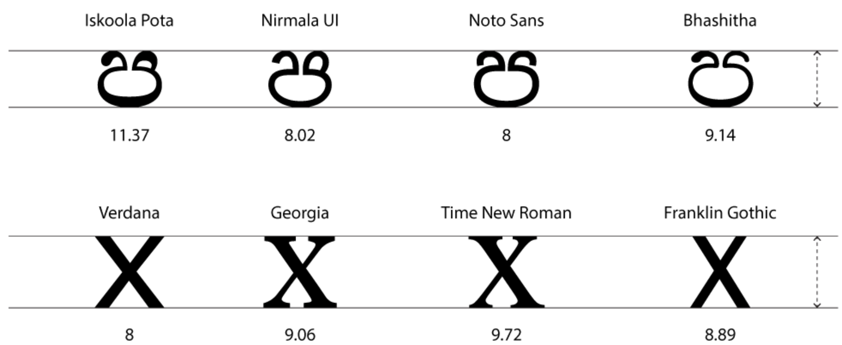


Figure 21: The differences in point sizes of different letters when their x-heights are normalized.

As seen in the figure above, the letters with the same x height can be of different point sizes. As an example, Iskoola Pota has a point size of 11.37 when its x height is normalized with other letters. This is not much of an issue in Latin scripts but when it comes to Sinhala, it affects the legibility in a considerable manner. So in order to alleviate this, the selected fonts were tested in different point sizes which corresponds to their normalized x heights.

3.7 Experiment on legibility for Sinhala fonts

An experiment was carried out to test the readability of each selected font in section 3.2.2. This part was essential to identify how well these fonts performed on a digital device interface and how successful they were in completing their intended task. The experiment consisted of reading out from a Sinhala text written in all the 4 typefaces on a mobile device screen. Then the time taken to read by a single participant is taken and the mean value is calculated for each typeface.

3.7.1 Material preparation

Participants were given a paragraph from a Sinhala book “Kaliyugaya – by Martin Wickramasinghe” to read in a pdf format. There were 4 separate text samples written in the selected 4 fonts and each individual was given only one of the 4 categories to read.

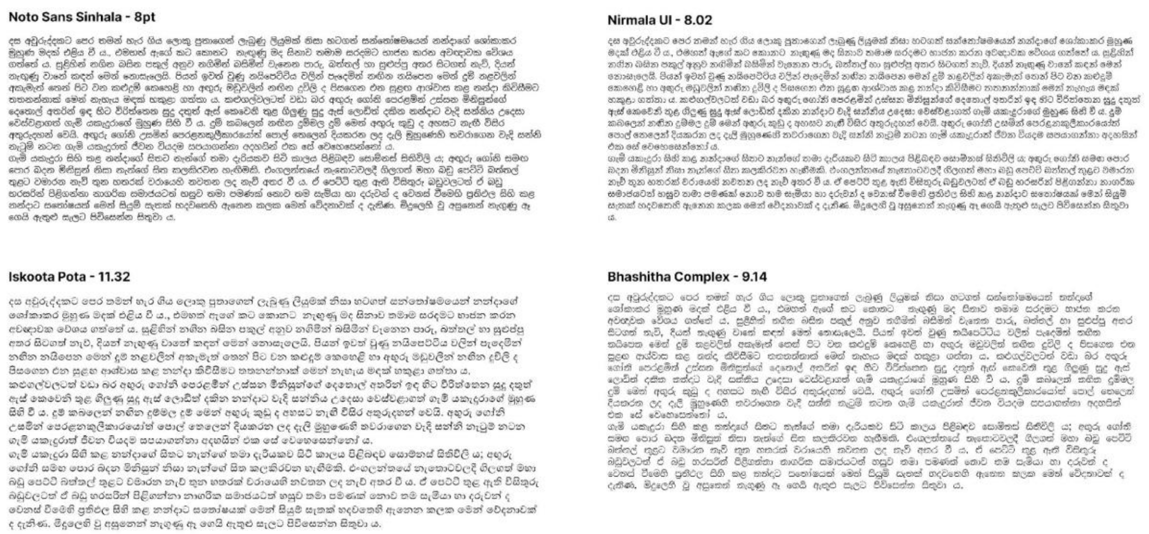


Figure 22 :Reading samples given for the participants. Point size of each font was adjusted in order to have a consistent x-height.

After the preparation of the reading material, a sample group of 120 students from University of Moratuwa was selected for this task. They were asked to read the prepared text in pdf format from a mobile device screen. The specifications of the mobile device screen were as follows.

- Samsung Galaxy A50
- Android 9.0 (Pie)
- Super AMOLED capacitive touchscreen, 16M colors
- Display size was 100.5 cm^2
- Resolution: 1080 x 2340 pixels with 403 ppi density

3.7.2 Methodology

According to Journal of the American Academy of Optometry, the average working distance for text messages for a smartphone user was found to be 36 cm but this distance was shortened to 32 cm when viewing a webpage.

To simulate that environment, the viewing distance was kept at 30 - 34 cm with the participants seated on a chair and the smartphone was given to their hand. The participants were then asked to read a text extracted from the text converted to pdf form to be displayed on the screen. One participant was only given one text to read and the time taken for the individual to finish the sample text was recorded. Assumption was taken that the level of comprehension remains constant across all the participants.

3.7.3 Results

When the results were analyzed, it was evident that Noto Sans Sinhala recorded the highest reading speed followed by Nirmala UI, Bhashitha and finally Iskoola Pota. This result led to the conclusion that Noto Sans Sinhala was the most legible typeface out of the four fonts selected.

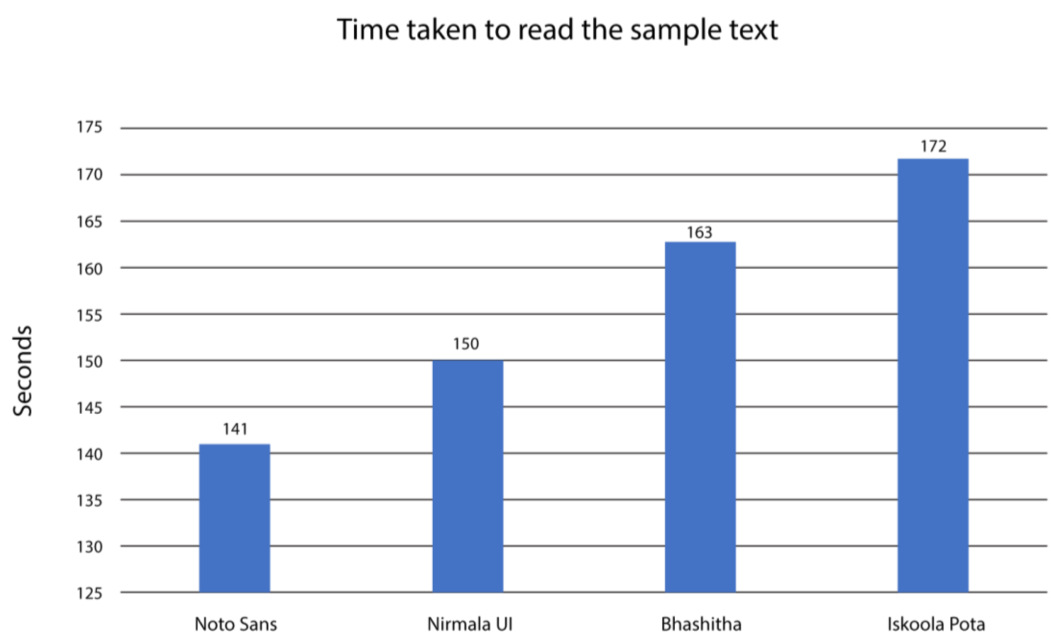


Figure 23: Time taken to read font samples by each font

One of the reasons that Noto Sans and Nirmala UI have a higher legibility is that they were developed together with several other international languages by a panel of type designers. These typefaces were commissioned by Google and Microsoft respectively to be included in their programs.

“Google has been developing a font family called Noto, which aims to support all languages with a harmonious look and feel” (www.google.com/get/noto/)

Since these fonts were specifically designed to perform as body fonts for digital interfaces, its performance in this scenario is justified. While Bhashitha and Iskoola Pota typefaces were designed by local typographers inspired by earlier print only typefaces present in Sri Lanka. Even though they tend to lack on the legibility aspect, Bhashitha and Iskoola Pota had an anatomy which closely resembles the base letter of Sinhala script. Between legibility and anatomical accuracy, the most effective method of designing a perfect font is finding the balance between these two factors.

With the justification of Noto Sans Sinhala being the most legible font from the selected sample, the next objective was to identify how this level of legibility is achieved.

3.8 Similar letter misidentification and legibility of Noto Sans Sinhala font

In Latin, there are a set of letters which are often misinterpreted due to its anatomical similarities. These characters include; e for o or c ; n for u ; i for 1 ; h for b, and a for s. (Grant, 1916) Similarly a set of commonly misidentified letters in Sinhala was also made. This was done through a visual analysis of DVF present in each letter. By using the method of superimposition Legros used for Latin scripts and applying them to the Sinhala letters, an analysis can be done on how these anatomically similar pairs were designed to look different in Noto Sans Sinhala typeface. The method of superimposition was used in finding these letters through a visual analysis.

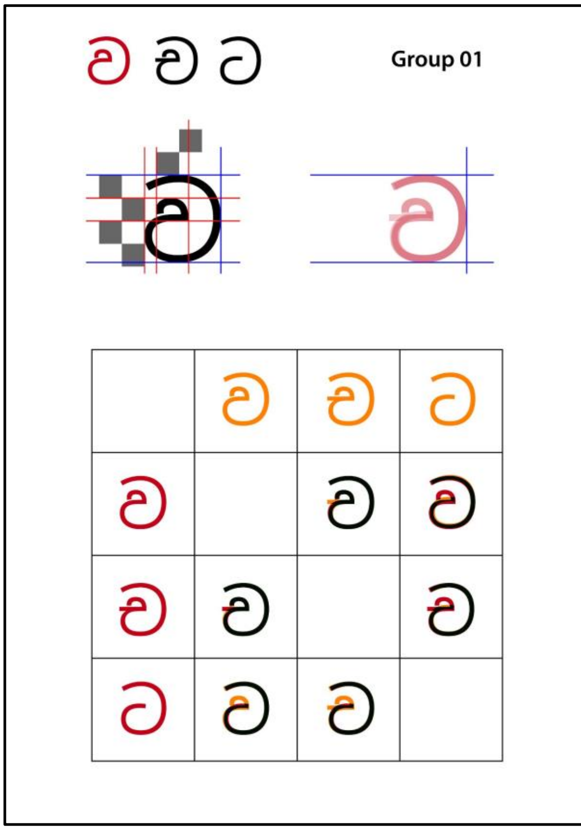
Figure 24: Letters 'Ha' (top) and 'Bha' (bottom) of the font Noto Sans Sinhala superimposed on top of eachother

The letters are superimposed over each other and the overlaying parts are recorded to identify the covered area. A sample of 15 letters across 5 sets were selected with a criterion to cover most widely confused letters in Sinhala script which has similar anatomy. As confusions with misreading anatomically similar letters is a common occurrence in low legible fonts, this method could identify the anatomical similarities and the differences of those selected letters.

3.8.1 Commonly misunderstood letters in Noto Sans Sinhala

Figure 24: Most commonly misidentified letters in the font Noto Sans Sinhala grouped according to their anatomically similar structures.

In a visual analysis, the above 15 letters can be identified as the most misread letters in the Sinhala alphabet. This is mostly due to the fact that there are very small differences in their anatomy. For example, the letters shown in the table, letter groups 01 and 03 show a change in anatomy with the DVF 'Eye' and an addition of a small horizontal stroke at the eye area. Similarly, other groups also had their similarities and differences in DVF which are summarized below;



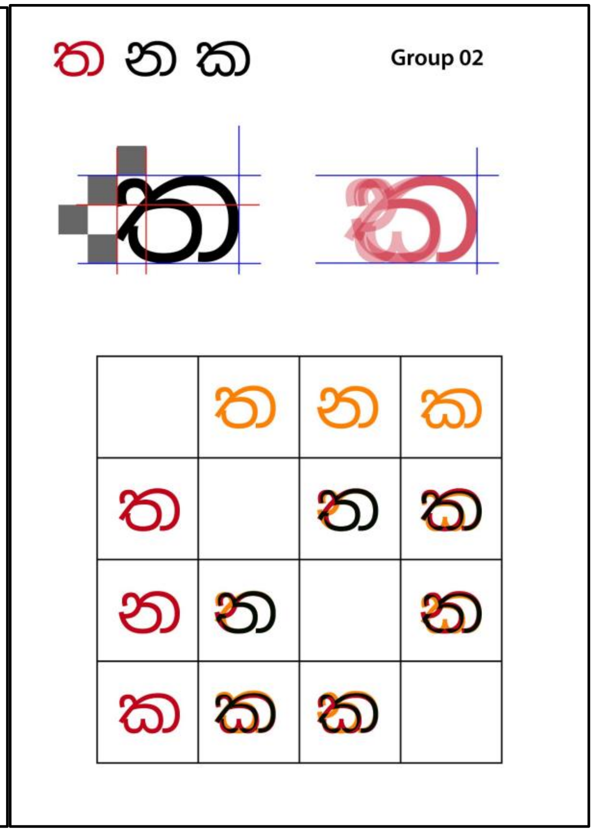
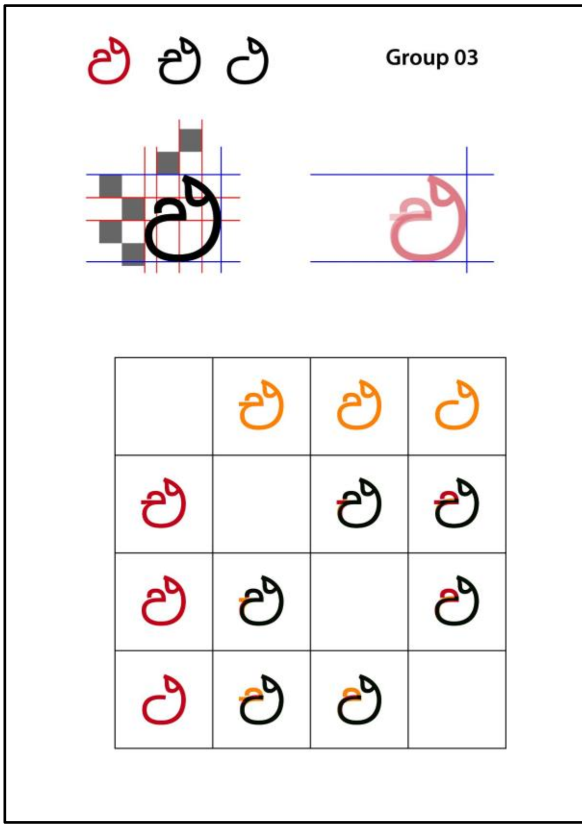


Figure 26: Group 01 (left)

Figure 27: Group 02 (right)



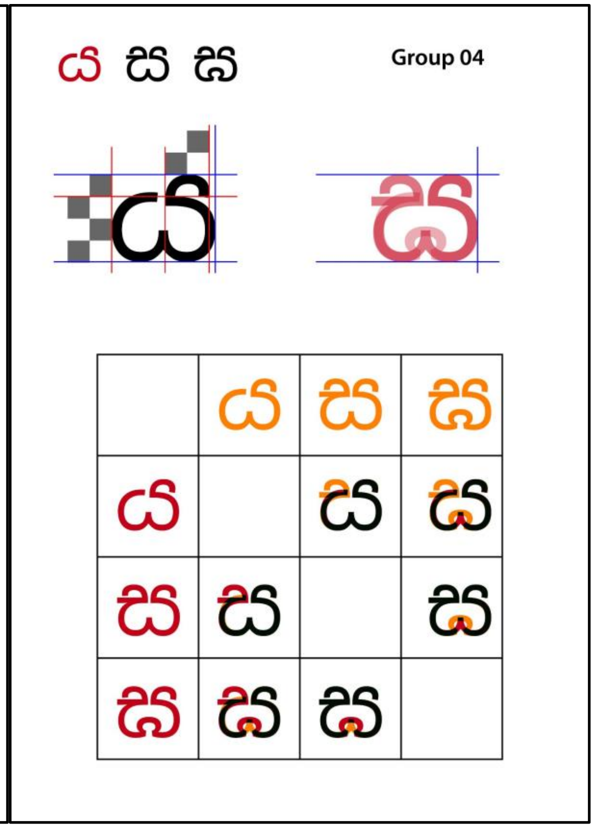


Figure 28: Group 03 (left)

Figure 29: Group 04 (right)

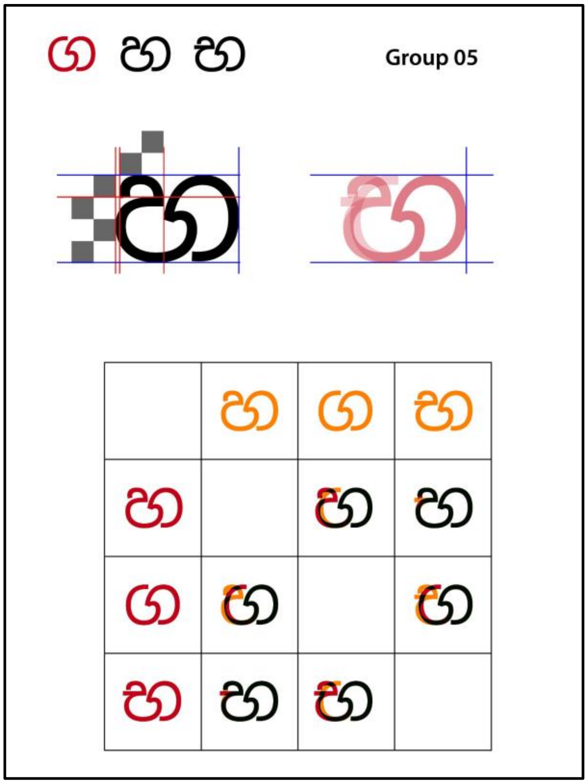


Figure 30: Group 05

Previous experiments focused on identifying the skeletal structure of the base letter along with its DVF which define the base shape of the Sinhala letter. The objective of this visual analysis was to identify a single font which can be analyzed and used in the coming experiments done in the next chapter. As the results implied, Noto Sans Sinhala has the highest legibility among the selected fonts and its anatomical features were analyzed.

3.9 Chapter Three Summary

This chapter was based on the relationship between the skeletal structure and the anatomical structure of the letter. It also discussed one of the major problems addressed in this research which is the lack of proper anatomical understanding of the Sinhala typefaces. Sinhala fonts face a major issue when analyzing its structure; different font variations carry different anatomical features even on identical letters. This problem was solved by identifying the skeletal structure of letters and understanding the anatomical features of Sinhala letters by using that skeletal structure as a basis. Then the chapter focused on identifying a proper basis in order to carry out the future experiments by introducing Distinct Visual features of the Sinhala letter which is made out of stroke primitives of the letter. These Distinct Visual Features were derived from the analysis of skeletal structure of the letter. It was also identified that these Distinct Visual Features also act as the main contributing factor to the similar letter misidentification of the letters within the same font which in turn leads to decreasing legibility.

The second part of the chapter focused on analyzing these distinct visual features across a variety of selected sample fonts in order to get a better understanding about how each of these features can affect the final anatomy of the letter. From these sample typefaces, a single typeface was selected in order to experiment into a more detailed analysis on the effects of distinct visual features on letter anatomy. The selection criteria was based on measuring the legibility of the typefaces and Noto Sans Sinhala had the highest legibility among the selected font samples. This paved the path to understanding the anatomical differences between letters of the same font. A group of commonly misidentified letters were selected by analyzing the distinct visual features of the font Noto Sans Sinhala and these letters were superimposed over each other to get an understanding on their skeletal structural changes. It became evident that these skeletal changes in the distinct visual features of the letters made these letters differentiate more from each other in order to prevent similar letter misidentification thus improving legibility. This assumption was further clarified by a legibility experiment which will be discussed in Chapter 04. This experiment was performed by altering the distinct visual features of these commonly misunderstood letters and testing out their legibility in a controlled environment.

CHAPTER 04: ANALYZING LETTER MISIDENTIFICATION AS A METHOD OF OPTIMIZING LEGIBILITY

Letter misidentification is a crucial factor that can impact the legibility of digital screens. Similarities in the shape and design of letters can lead to confusion and errors in reading, resulting in reduced comprehension and misunderstandings. In order to alleviate these nuances, one of the methodologies that can be adopted is the optimization of the fonts used in these contexts. The previous chapter established what factors affected the legibility of a font in the context of letter anatomy. It was also established that one of the main factors which affects the legibility is the occurrence of similar letter misidentification of letters in the same font. Previous chapter also analyzed several sample fonts and their legibility under controlled conditions, eventually singling out one font which had the highest legibility out of the selected sample.

This chapter mainly focuses on analyzing the previously selected font Noto Sans Sinhala with special focus on the factor of similar letter misidentification in two parts. The first part is based around the analysis of the anatomical features of the identified font Noto Sans Sinhala which contributes to similar letter misidentification. These features were analyzed for their highly deviating areas and a sample of letters were created by altering these DV features. Then the altered features were investigated for the impact of those alterations through a Short Exposure legibility test. The second part of this chapter focuses on the impact on legibility brought about by the above said anatomical changes to the letter features in Noto Sans Sinhala. It analyzes the changes made and their respective effects on legibility in order to arrive at a meaningful conclusion. The result can be used to impose visual parameters of each anatomic feature which can be manipulated to optimize legibility.

4.1 Impact of distinct visual features in font legibility with special reference to Noto Sans Sinhala font

The distinct visual features (DV Features) of a font play a crucial role in its legibility and readability. DV Features refer to the unique anatomical markings in a font that differentiate one letter from another in its skeletal form. These features help to address the problem of similar letter misidentification, which can occur when two letters look too similar to each other. This can lead to confusion and errors, particularly when reading quickly or in low-light conditions. Therefore, it is important to consider DV Features when designing fonts to ensure legibility and readability.

In Chapter 03, the impact of DV Features on legibility in the Noto Sans Sinhala font was analyzed. The results showed that Noto Sans Sinhala had the highest legibility compared to other fonts in the sample range. The font's unique DV Features were instrumental in achieving this result. By carefully designing and implementing distinct anatomical features, Noto Sans Sinhala was able to minimize the problem of similar letter misidentification, which in turn led to increased legibility and readability.

Furthermore, the analysis of Noto Sans Sinhala demonstrated that the font's unique features were able to address similar letter misidentification between letters of the same font. This is an important consideration for fonts used in digital platforms, where users may need to read quickly and efficiently in various screen size conditions. This analysis was done with the method of superimposition and results showed a range of letters which were commonly misunderstood due to their anatomical similarity.

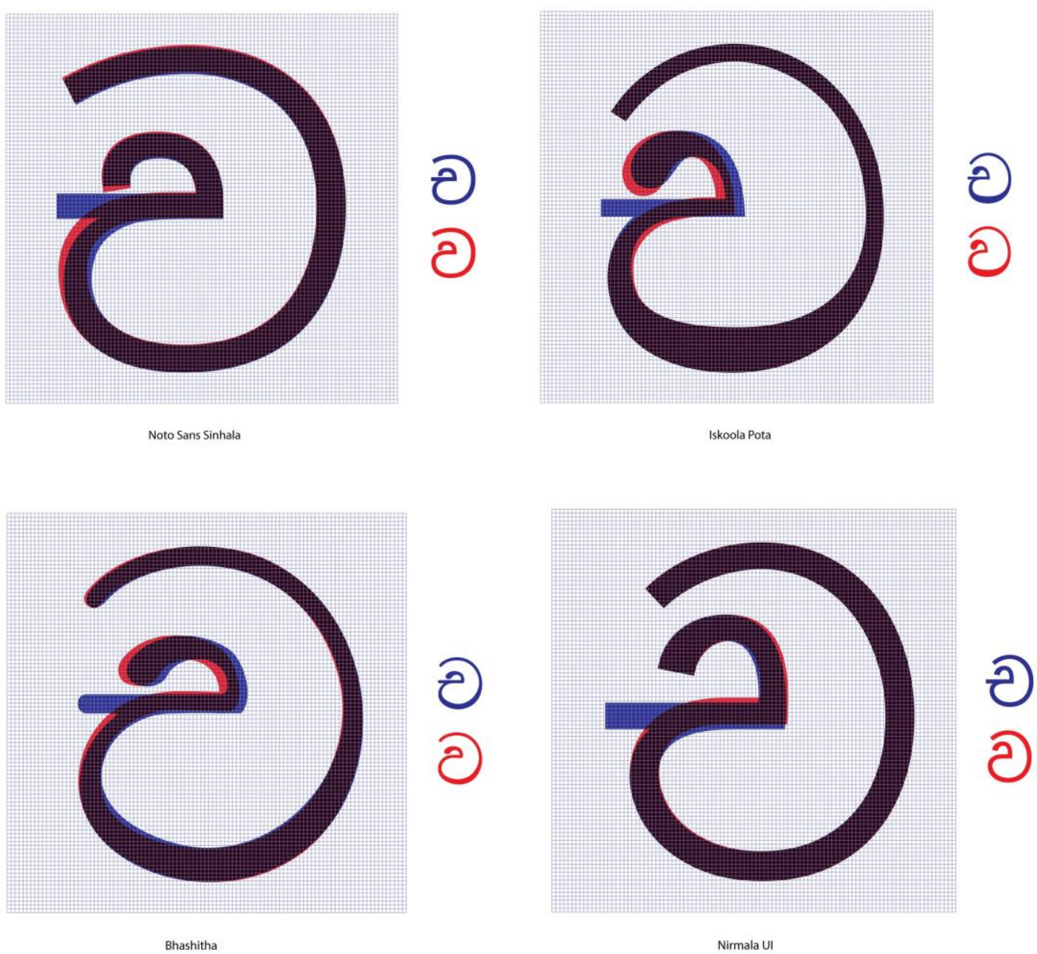


Figure 31: Superimposed letters ‘Cha’ and ‘Wa’ of different fonts Noto Sans (top,left) Iskoola Pota (top,right) Bhashitha (Bottom,left) and Nirmala UI (bottom,right)

4.1.1 Using superimposition as a method of identifying High Deviating Areas

Superimposition is a powerful tool used by typographers and typeface designers to identify high deviating areas in a font. This method involves overlaying two letters of the same typeface on top of each other and closely analyzing the areas where they do not align properly. These areas of misalignment, known as high deviating areas, can be identified by carefully observing where the edges of each letter overlap, and where they diverge from each other as explained in the previous chapter.

High deviating areas refer to the parts of a letter that have the most variation when the letter is superimposed on another letter. These areas are important in determining the legibility of a font as they can contribute to the confusion between similar letters. The high deviating areas can differ between different fonts and even between different styles of the same font. Even though high deviating areas can also depend on the font size, weight, and spacing of a font, these factors are kept constant through analyzing deviance across letters of the same font. In this case Noto Sans Sinhala.

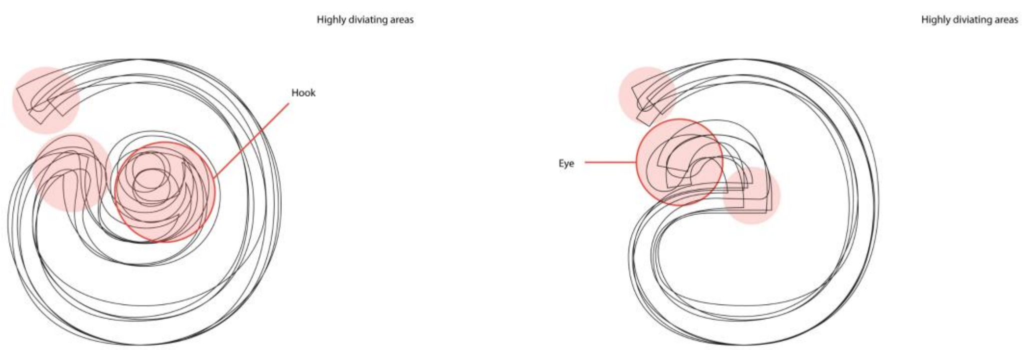


Figure 32: Superimposition of the same letter 'Ma' (left) and 'Wa' (right) with different fonts.

These areas of misalignment can provide insight into which features of the letter are causing confusion. By analyzing these areas, the letters' features can be adjusted to reduce the likelihood of confusion with similar letters. Identifying these highly deviating areas can lead to the identification of distinct visual (DV) features which affect font legibility.

4.1.2 Understanding the impact of DV features on letter legibility by changing highly deviating areas

The legibility of a font can be influenced by the differences in its distinct visual features (DVF) as identified in Chapter 02. Highly deviating areas in a letter can be identified by superimposing the same letter in different fonts. Alternatively similar letter misidentification can also be analyzed by this method of superimposition by overlaying anatomically similar letters of the same font. By altering the DVF in highly deviating areas of a letter in controlled conditions, the impact of these features on legibility can be identified. This approach was applied to the Noto Sans Sinhala font.

In this experiment, the previously selected 5 groups of commonly misidentified letters were selected based on a visual analysis. The superimposition method was employed to analyze the anatomical features of each group. This method involved overlaying each letter on top of the other to identify areas where they deviated from each other.

By superimposing the group of letters together, the anatomical features that were similar and different among the letters were identified. The highly deviating areas, where the letters did not align perfectly, were identified as potential sources of similar letter misidentification. This approach enabled the researchers to identify specific features that could potentially cause confusion for readers and impact the legibility of the font.

Figure 33: Superimposition of different letters 'Ha' (top), and 'Bha' (bottom) of the same font Noto Sans Sinhala. These two letters are one of the most commonly misidentified letters in Sinhala.

This section of the chapter aims to investigate the impact of altering DV features in highly deviating areas of letters on similar letter misidentification. To achieve this, a sample of 15 letters that were previously identified as commonly misidentified were selected. For each letter, the DV features in the highly deviating areas were modified, resulting in a range of letter samples with altered features.

By altering the DV features in the highly deviating areas of letters, it was determined how these modifications affect legibility and the potential for similar letter misidentification. The range of modified letter samples allowed for a comprehensive analysis of the impact of specific DV feature alterations on the legibility of the letters.

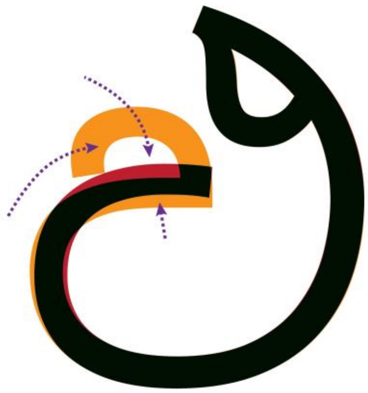


Figure 34: How changes are done to the letters 'Tha' and 'Eh' superimposed. Their non overlapping areas in the DVF are changed.

In this study, variations of each letter were drawn with changes made to specific DV features in the highly deviating areas. The variations were categorized into three levels of distortion: **Low Distortion, Medium Distortion, and High Distortion.** A total of 45 sample letters were created in this manner from the group of 15 letters. (5 groups with 3 letters in each group)

The purpose of creating these variations was to analyze the effect of different levels of distortion on the legibility of the letters and the potential for similar letter misidentification. By categorizing the distortions into three levels, we were able to examine the impact of varying degrees of DV feature alteration on legibility and identify which level of distortion is the most effective for improving legibility and reducing errors.

The below example shows the letter 'Ka' modified. Its DV Feature 'Curve to Curve Joint' was identified as the main deviating feature from its group (Group 02) of commonly misidentified letters. In this case the affected DV Feature was altered by increasing the counter space of the letter.

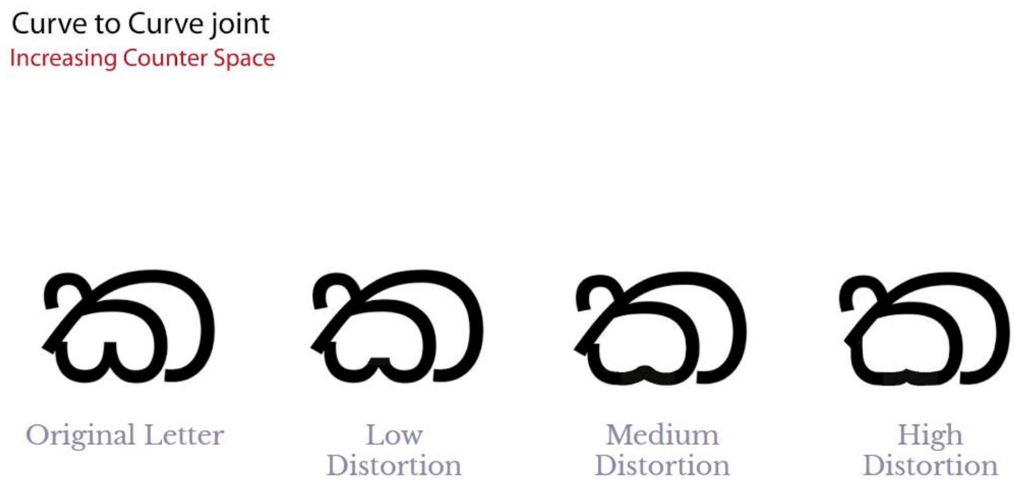


Figure 35: Three different variations of the letter 'Ka' that were created by altering its DV Feature 'Curve to curve joint'. The alteration done here was increasing the counter space inside the letter.

Similarly, the other letter groups were also modified in the same manner. The method of alteration was different due to the anatomical differences in their DV features. Below shows some of the examples;

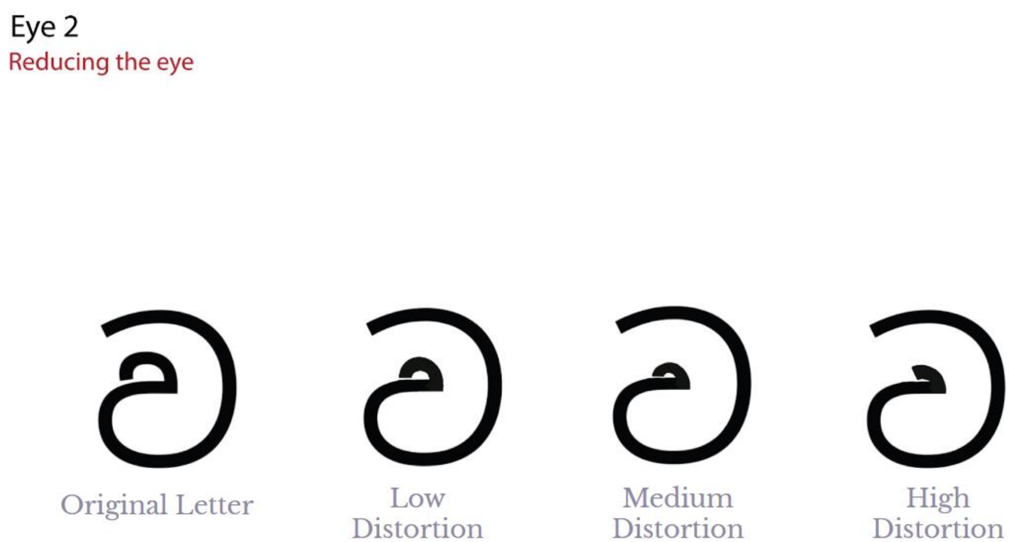


Figure 36: Three different variations of the letter 'Wa' that were created by altering its DV Feature 'Eye 02'. The alteration done here was reducing the size of the eye of the letter.

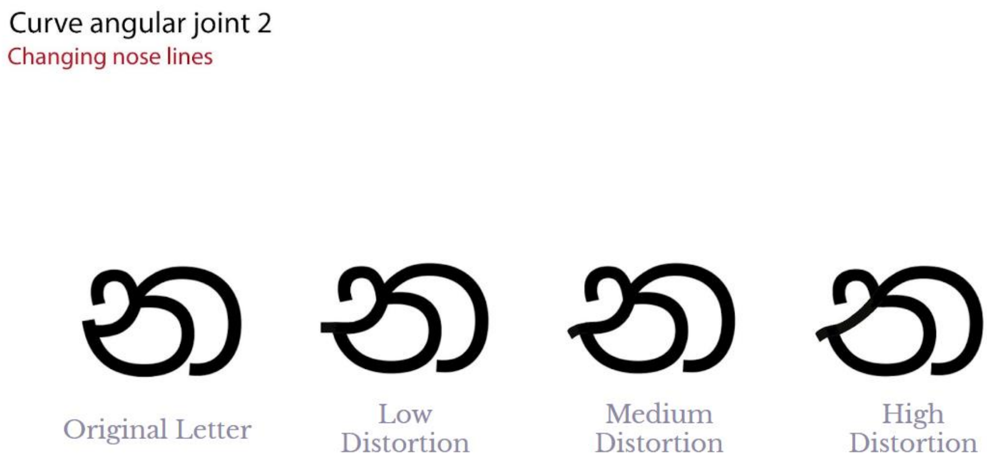


Figure 37: Three different variations of the letter 'Na' that were created by altering its DV Feature 'Curve Angular Joint 02'. The alteration done here was changing its nose lines.

Through this method, it was possible to determine which specific DV features in the highly deviating areas of letters have the greatest impact on legibility and which levels of distortion are most effective in optimizing legibility. This information can be used to inform the design and modification of fonts to reduce similar letter misidentification and improve overall legibility.

4.1.3 Experimenting with the impact of anatomic features on legibility in Noto Sans Sinhala font using short exposure method

The impact of DV features of letters on legibility was investigated in this study through an experiment that involved using the above developed set of altered sample letters and testing their legibility using a short exposure legibility testing method. The aim of this experiment was twofold: first, to confirm whether DV features do indeed affect similar letter misidentification and, in turn, legibility; and second, to determine to what extent these features could be altered when creating a Sinhala digital font without compromising legibility. By conducting this experiment, the objective was to gain a better understanding of the specific features of Sinhala letters that affect legibility and how these features can be optimized in digital font design.

The Short Exposure Legibility (SEL) testing method was developed by Sophie Beier as a way to assess the legibility of typefaces in a short amount of time. This method is based on three earlier testing methods: the Pyke Test, Tinker Test, and Ovink Test.

The Pyke Test, developed by A.W. Pyke in 1966, involves showing subjects a series of letter pairs and asking them to identify which letter in each pair is more legible. The Tinker Test, developed by Miles Tinker in 1963, involves measuring the time it takes subjects to identify individual letters. The Ovink Test, developed by Robert Ovink in 1975, involves measuring the time it takes subjects to read a block of text.

Sophie Beier combined elements of these three tests to develop the SEL method. In this method, subjects are shown a series of three-letter words in a random order, with each word displayed for only 42 milliseconds. The subjects are then asked to write down as many words as they can remember.

These results can be used to assess the legibility of different typefaces. Typefaces that are more legible will be easier for subjects to remember and will result in fewer misread or misunderstood words. The SEL test can also be used to assess the legibility of different font sizes, spacing, and other typographic features. Overall, the SEL test provides a quick and effective way to evaluate the legibility of different typefaces and other typographic elements.

a) Font sample preparation

A total sample of 60 letters were taken as the test sample. This included the 45 letters that were created previously by altering its DV features (15 low distortion, 15 medium distortion, 15 high distortion letters.) and the 15 original letters. But after the first test run, there was no apparent distinction recorded between the letters with medium distortion and the other two altered groups; low distortion and high distortion. Hence the letter group of medium distortion was discarded and the test was redone using 45 letters. These distortions were done based on their availability on misidentified DV features. Hence letters with more than one DV feature have more variants of distorted letters. Each letter was assigned a number associated with it. This numbering was done for convenience for later when the final data was analyzed and plotted against the graph.

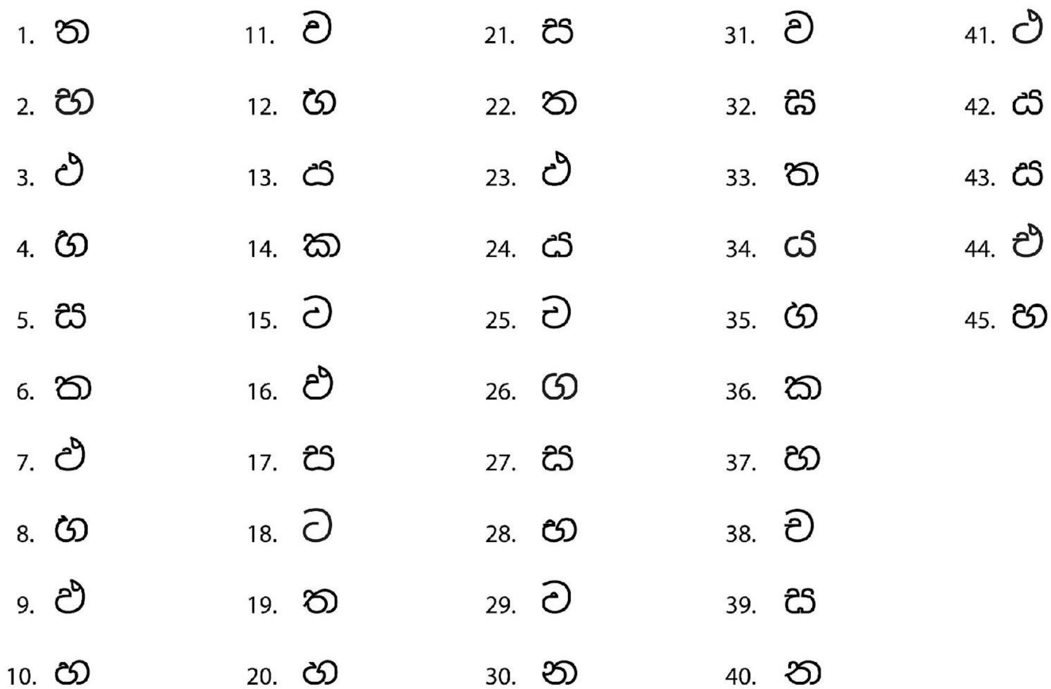


Figure 38: The set of 45 letters that was used for the experiment. This includes 15 original, 15 low distortion and 15 high distortion letters. The letters were arranged randomly in sequence to be viewed by the user.

b) User group

For the experiment on font legibility, a user group of 100 students was selected from a specific age group of 23 to 27 years. It was assumed that their eyesight and font comprehension remained constant throughout the study. They were all fluent in the Sinhala language and had a high level of education. As the study aimed to investigate the legibility of Sinhala digital fonts, it was important to select participants who were familiar with the language and its writing system. The participants were informed about the purpose and nature of the experiment and provided their consent to participate. The experiment was conducted in a controlled environment to ensure consistent conditions for all participants

c) Experiment setup

The experiment on font legibility was conducted in a controlled environment using personal computers with the Windows 7 operating system in a room with 30 personal computers, all with constant lighting conditions throughout. Each participant was provided with an LCD/QHD screen measuring 24 inches with 1280*720 pixels resolution at 122PPI. The viewing distance was set in the range of 50-100 cm from the screen, which is a typical viewing distance for computer screens. The screen size, resolution, and viewing distance were selected to ensure a comfortable viewing experience for participants and to minimize any potential sources of visual discomfort or distraction. The use of consistent technology and viewing conditions across all participants ensured that the experiment could be conducted under controlled conditions, which is important for accurate data analysis.

Figure 39: The experiment was conducted in a room with 30 personal computers, with 100 participants taking turns in 4 batches all with constant lighting conditions throughout. Each participant was provided with an LCD/QHD screen with the prepared materials on display.

d) Methodology

The custom-made interactive prototype used in the experiment was created with Figma, a design tool that allows for the creation of prototypes and user interfaces. The prototype was designed to display the altered letters to participants in a standardized and consistent way. The window size of the prototype was set to 520x512 pixels, with a white background, to ensure that the focus was on the letters being displayed. The letters were displayed 2 cm from a focal point represented by a red dot in the center of the screen. This was done to ensure that participants maintained a consistent viewing distance of 50 cm away from the screen during the experiment.

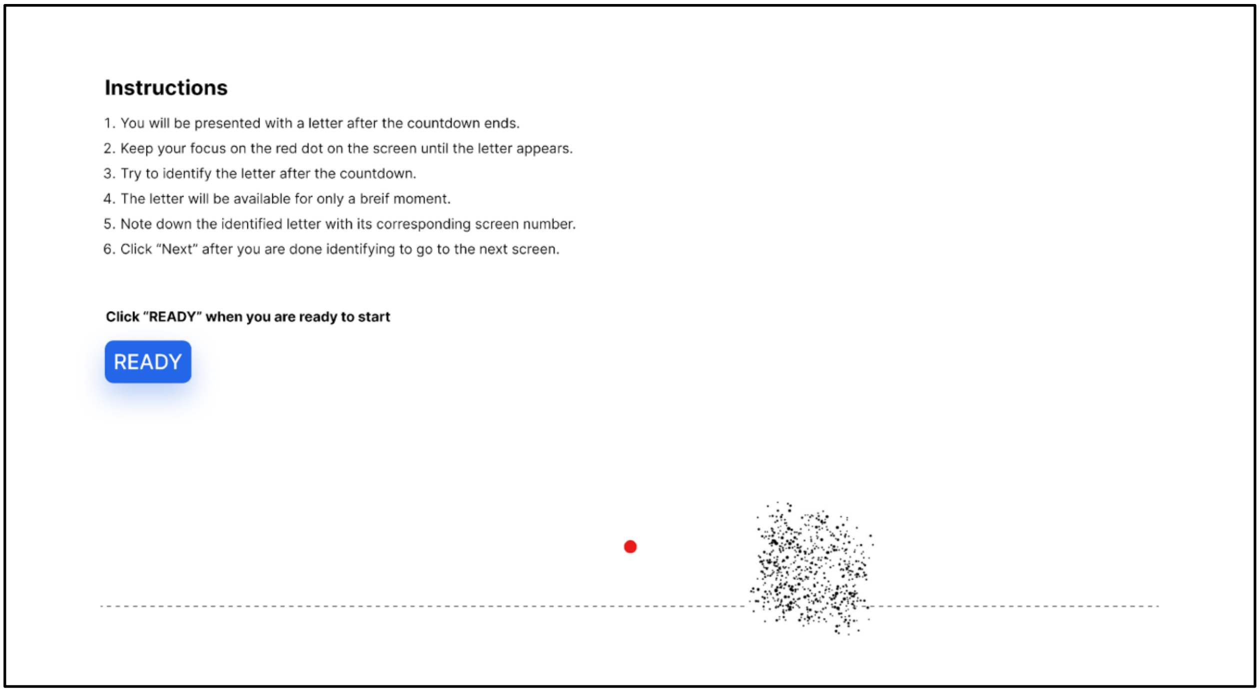


*Figure 40: **Step 01:** The participants were shown this screen at the start with instructions on how to proceed. When the participant clicked the "Ready" button, the first letter was displayed.*

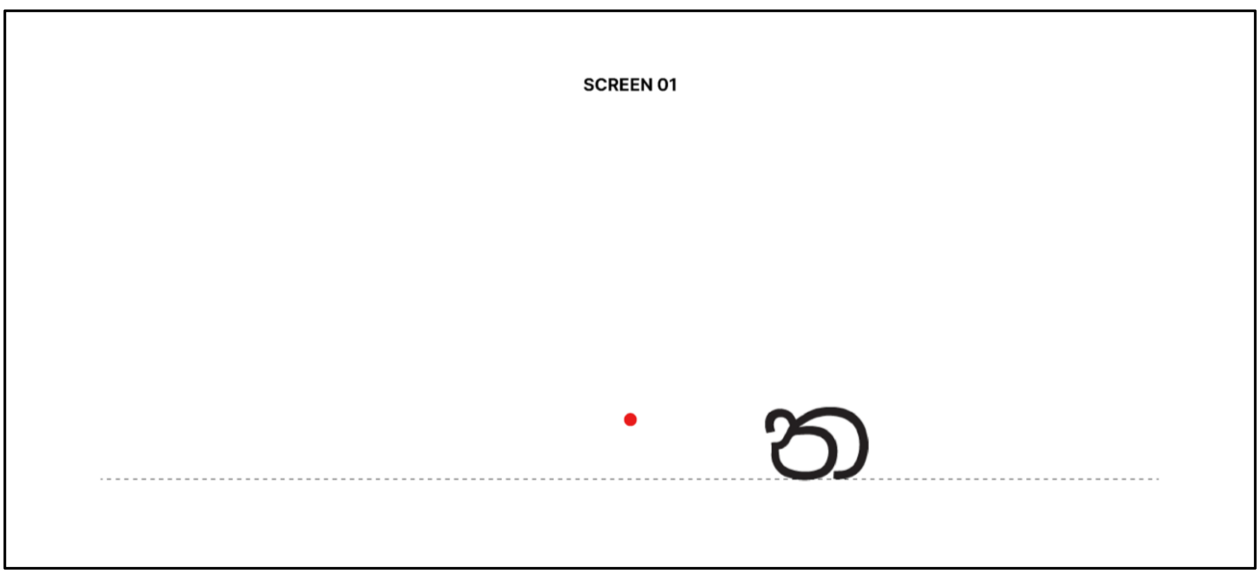


*Figure 41: **Step 02:** Participants were asked to keep focusing on the red dot while the letter was displayed for a brief period of time (50 milliseconds)*

Participants were instructed to focus on the red dot as they were exposed to altered letters for a brief duration of 50 milliseconds. After each letter exposure, a mask was used to remove the afterimage of the letter. The mask consisted of a cluster of black dots and remained on the screen until the participant clicked the “Next” button to proceed to the next letter. This approach ensured that the afterimage of the previous letter did not interfere with the identification of the subsequent letter. All 45 sample letters were displayed to the participant in sequence. This method of testing ensured that participants were exposed to each letter for the same duration, and any differences in legibility could be attributed to the altered features of the letter rather than differences in exposure time or viewing distance.

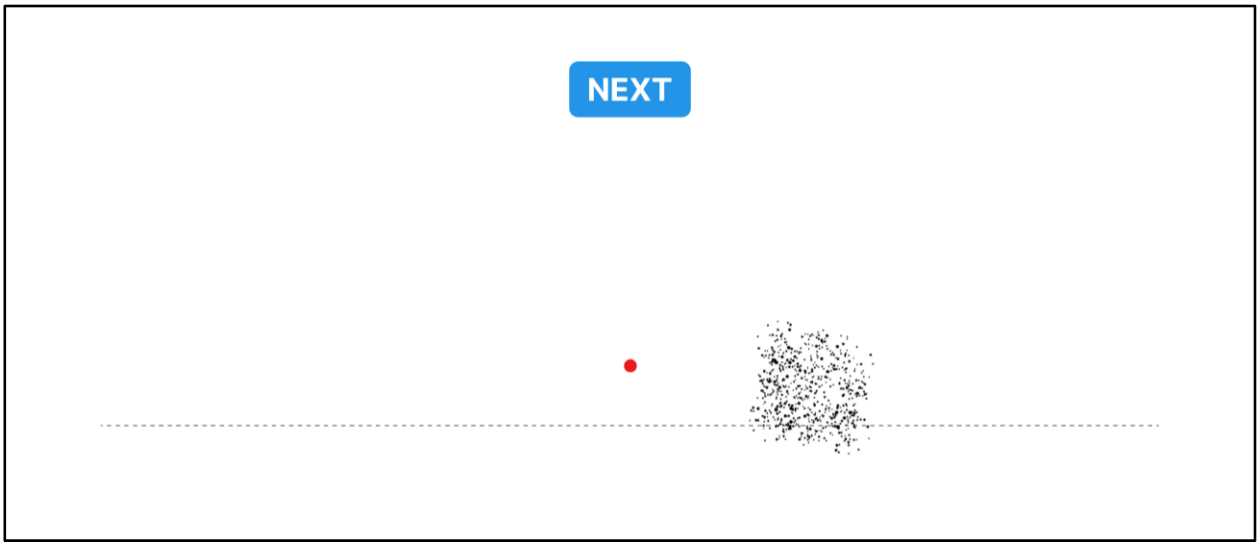


Figure 42: ***Step 03:*** *After the letter was exposed for 50 milliseconds, a mask was used to remove the afterimage. The participants had the ability to proceed at their own speed by clicking the “Next” button which took them to the next letter.*

To record participant responses, a physical form was provided to each participant, in which they had to write the letter they identified. The use of a physical form to record responses ensured that the data collected was reliable and could be easily analyzed. Participants had to write their responses, rather than selecting a letter from a list, to avoid any potential bias that may have been introduced if they were presented with a limited number of options. Additionally, the physical form allowed for the collection of data from participants who may have had difficulty using a computer or touchscreen device. By using a physical form to record responses, the experimenters were able to collect accurate and reliable data on the legibility of the altered letters.

e) Results

Once the experiment on font legibility was conducted and the participants' responses were recorded, the identified and misidentified letters were calculated as a percentage to determine the difficulty level of each sample. Percentage was calculated by identifying how many participants identified one particular letter out of 100. The goal was to identify which samples were the easiest or the hardest to identify. The results were then plotted against a graph, with the letter number as the x-axis and the percentage as the y-axis. This approach was used to create a visual representation of the data collected from the experiment.

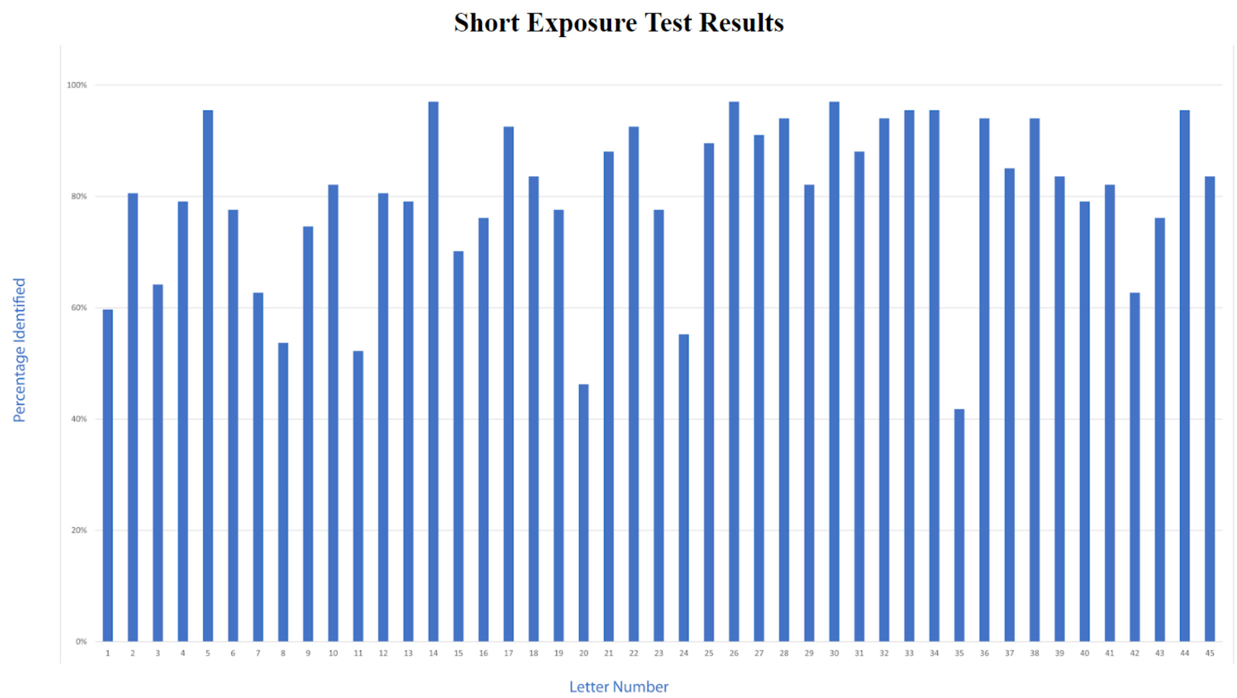


Figure 43: The graph of 45 letter samples plotted against the percentage of identification by the participants.

f) Findings

The results of the experiment on font legibility have provided valuable insights into the impact of DV features on letter recognition. Through the analysis of the participants' responses, it was possible to identify which letters were the most and least recognizable, and how their recognition rates were affected by the alteration of their DV features. Specifically, it was found that the letters that retained their original fonts without any alterations to their DV features were the most easily recognizable, while letters with high distortion to their DV features were the least recognizable.

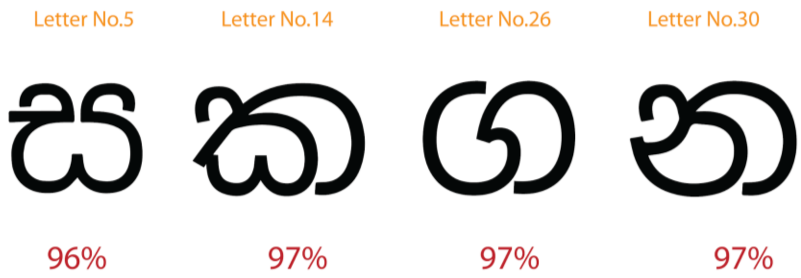


Figure 44: The most recognized letters were numbers 5, 14, 26, and 30, which were all original fonts without any alterations to their DV features.

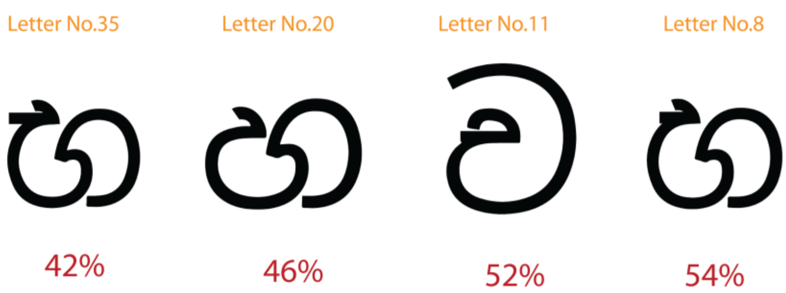


Figure 45: The least recognized letters were numbers 35, 20, 11, and 8, which were all letters with high distortion to their DV features.

The results showed that the most recognizable letters were the ones that were in their original form without any alteration to their DV features. In contrast, the least recognizable letters were the ones with high levels of distortion to their DV features.

These findings suggest that the DV features play a crucial role in determining the legibility of a font. When the DV features are altered to a significant degree, it can negatively impact the legibility of the font. Therefore, it is important to consider the impact of DV features when designing fonts to ensure that they are legible and readable.

Overall, the experiment's findings provide insights into the factors that affect the legibility of fonts and highlight the importance of DV features in font design. By understanding the impact of DV features on legibility, designers can create fonts that are easier to read and improve the user's reading experience.

The experiment also demonstrated the effectiveness of using superimposition as a method for identifying highly deviating areas in letters and understanding how these areas contribute to similar letter misidentification. By identifying the distinctive visual features of letters, the legibility of fonts can be optimized, and errors in reading can be minimized.

4.2 Analysis on how the anatomic features were structured in Noto Sans to reduce similar letter misidentification

The results of the visual analysis showed that Noto Sans Sinhala had certain anatomic features that were structured in a way to reduce similar letter misidentification and increase legibility. This part of the chapter focuses on analyzing those said features and comparing them with other fonts which had lower legibility values. In this case, the font 'Iskoola Pota' was used as a comparison due to having the lowest legibility from the 4 fronts identified in Experiment 01 in Chapter 4.1

This visual analysis using superimposition was done to identify two key observations;

1) To identify how the anatomic features were structured in Noto Sans original undistorted letters to increase the legibility.
2) To identify how the letters of Noto Sans Sinhala became less legible when the DV features are distorted using "Iskoola Pota" font as a reference baseline.

Overall, the analysis showed that the anatomic features of Noto Sans Sinhala were specifically structured to reduce similar letter misidentification and increase legibility, highlighting the importance of careful design choices in font creation

4.2.1 Comparison of fonts Noto Sans Sinhala with Iskoola Pota to identify structural differences which affect similar letter misidentification.

When analyzing the anatomic features of Sinhala letters in Noto Sans Sinhala compared to Iskoola Pota, 4 of the least legible letters were selected from the Short Exposure Legibility test.

For example, the letter "භ" (Bha) in Noto Sans Sinhala had a more distinct vertical line and a wider horizontal bar at the DV feature "Eye" compared to Iskoola Pota, which made it easier to distinguish from similar letters such as "හ" (Ha). Similarly, letter ව (Va) and ච (Cha) had a similar anatomical structure where the differences lied at the horizontal bar at the DV feature "Eye".

In the distorted version of the letter, these features were reduced and hence it showed more potential for similar letter misidentification than its unmodified counterparts.

Figure 46: Least legible letters of Noto Sans compared with Iskoola Pota font from left to right, Bha (Low Distortion), Ha, Cha and Bha (High Distortion)

On the other hand, most successfully identified letters had some features in common in them; which were having several areas of high deviation and prominent distinct visual features. These characteristics made the letters more unique and hence even if one feature was distorted, they could still be identified with a different DV feature.

Figure 47: Most legible letters of Noto Sans compared with Iskoola Pota font from left to right, Sa, Ka, Ga and Na

The legibility of a font plays a significant role in how effectively it conveys its message to the reader. Through the experiments and visual analyses conducted in this study, it is clear that the anatomic features of a font have a considerable impact on its legibility. The findings suggest that fonts with more distinct and easily identifiable anatomic features are more legible compared to fonts with less distinct features.

4.3 Increasing legibility of a font by removing similar letter misidentification

As this chapter established earlier, legibility of a font can be improved by reducing the chances of similar letter misidentification. When certain letters in a font have similar features, it can make it difficult for readers to distinguish between them, leading to mistakes in reading and comprehension. This can be alleviated by altering its DV features which involve making subtle changes to the curves, angles, and thicknesses of certain letters to make them more distinct from each other. By reducing the potential for confusion between similar letters, the legibility of the font can be improved, making it easier for readers to quickly and accurately read and understand the text.

During previous experiments Iskoola Pota has been noted to have lower legibility compared to other Sinhala fonts. One of the reasons for this is that when similar letters in Iskoola Pota are superimposed, their distinguishing visual (DV) features, such as the placement and orientation of strokes, did not show much difference in their anatomy. This can make it difficult for readers to distinguish between similar letters, leading to errors in reading.

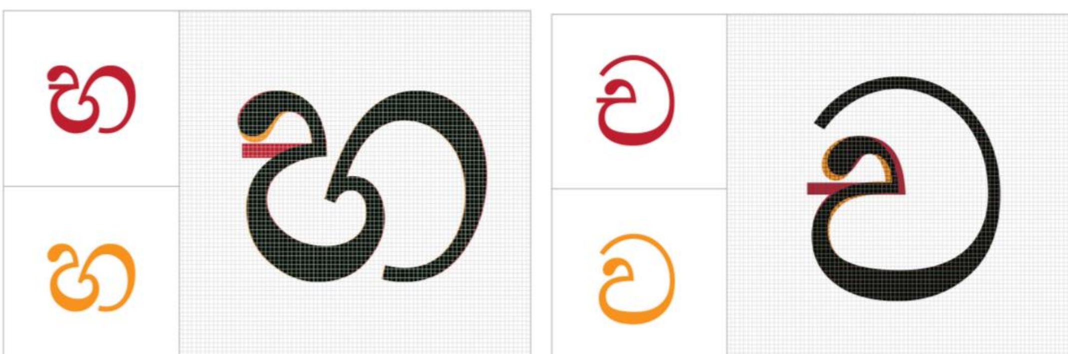


Figure 48: Left: Superimposition of letters Bha (top) and Ha (bottom) from Iskoola Pota font. Right: Superimposition of letters Cha (top) and Va (bottom) from Iskoola Pota font.

On the other hand, Noto Sans Sinhala was designed with particular attention paid to the anatomy of its DV features. When similar letters in Noto Sans Sinhala are superimposed, their unique DV features are more distinguishable compared to Iskoola Pota

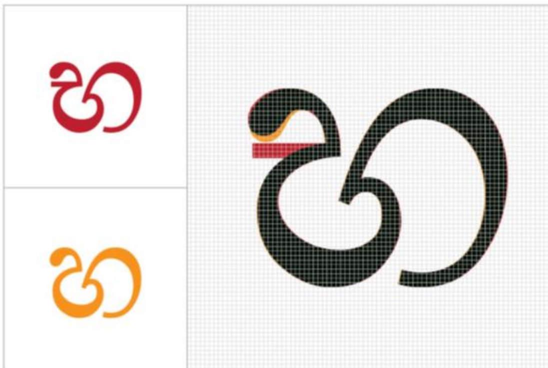



Figure 49: Left: Superimposition of letters Bha (top) and Ha (bottom) from Iskoola Pota font.
Figure 50: Right: Superimposition of letters Ha (top) and Bha (bottom) from Noto Sans font.

In conclusion, the visual analysis of Noto Sans Sinhala and Iskoola Pota fonts showed that the anatomic features of the former were structured in a way that reduced similar letter misidentification and increased legibility. In contrast, Iskoola Pota font had lower legibility due to its similar DV features of letters when superimposed. The unique DV features of Noto Sans Sinhala, on the other hand, showed distinguishable differences when superimposed, which increased its legibility. These findings provide important insights into the design of Sinhala digital fonts and the impact of DV features on legibility. They can be used to inform the development of new fonts or the improvement of existing ones to enhance legibility and reduce errors in Sinhala text. Further research can be conducted to test the legibility of other Sinhala digital fonts and explore additional factors that can affect legibility in Sinhala text.

4.4 Chapter Four Summary

Chapter 04 of this research thesis investigated the impact of distinct visual (DV) features on the legibility of Sinhala digital fonts. Through the superimposition method, highly deviating areas of letters were identified and modified at three levels of distortion to understand the impact on legibility and similar letter misidentification. The experiment involved 100 Sinhala-literate students aged 23-27 using a Short Exposure Legibility (SEL) test to assess the legibility of different typefaces, including font sizes and spacing.

The experiment found that alterations to the DV features of Sinhala letters can compromise legibility, particularly when the distortion level is high. However, specific features such as the size of the DV feature, the shape of the consonant stroke, and the placement of vowel signs were found to be critical in optimizing legibility. Even small changes in the anatomic features of letters can have a significant impact on legibility, highlighting the importance of considering DV features and high deviating areas when designing fonts for optimal legibility and readability.

Furthermore, the study compared Noto Sans Sinhala with Iskoola Pota, which had the lowest legibility score, to understand the impact of anatomic features on legibility. The visual analysis of Noto Sans Sinhala showed that its unique DV features were designed to reduce similar letter misidentification and increase legibility. Certain letters in Noto Sans Sinhala had distinct anatomic features, such as a vertical line and a wider horizontal bar, making them easier to distinguish from similar letters. Conversely, in Iskoola Pota, similar letters had less distinguishing visual features in their anatomy, leading to errors in reading.

Overall, the results of this chapter highlight the importance of considering anatomic features and DV features in the design and modification of Sinhala digital fonts for optimal legibility and readability. By understanding the specific features that affect legibility and similar letter misidentification, designers can make subtle changes to the curves, angles, and thicknesses of certain letters to make them more distinct from each other. This can ultimately improve the legibility of Sinhala digital fonts and enhance the conveyance of messages to readers.

CHAPTER 05: CONCLUSION

The aim of this study was to **investigate the anatomical features of Sinhala typefaces that contribute to optimizing legibility on small-scale digital device screens**. Through an extensive review of the literature and data analysis, this study has provided insights into several key points that were identified. The presented methodologies were specific to Sinhala scripts and were used to analyze its legibility studies. The DV features of letters were defined to optimize legibility for small digital screens. It was found that the legibility of a font was directly affected by anatomical changes done to their DV features. The legibility of a Sinhala font could be improved by reducing similar letter misidentification, which was identified as a significant factor affecting legibility. The study showed that similar letter misidentification in Sinhala fonts was caused by the lack of distinction between their DV features. It was concluded that the legibility of a font could be improved by adjusting the DV features of the most commonly misidentified letters.

In this concluding chapter, the key findings will be summarized, and their implications will be discussed. Additionally, the limitations of the study will be acknowledged, and recommendations for future research will be suggested. Overall, this conclusion chapter aims to provide a comprehensive understanding of the research findings and their significance for the field.

5.1 Objectives of the research

The research aimed to achieve two objectives. Firstly, the role of general anatomical features of a script that contributed to designing a font for legibility on small-scale digital device screens was identified by reviewing existing literature on typography, legibility, and digital content design. Key design factors contributing to legibility on digital screens were understood through this literature review.

Secondly, the specific anatomical features of Sinhala typefaces that contributed to optimizing legibility on small-scale digital device screens were identified. The research analyzed various design parameters unique to Sinhala script, such as stroke weight, x-height, contrast, letter-spacing, and other anatomical factors, to identify the optimal combination of features that enhanced legibility on digital screens.

i. Identify the role of anatomical features of a script which contribute to designing a font for a purpose (in this case legibility)

Ii. Identify the anatomical features of Sinhala typefaces that contribute to optimizing legibility of small-scale digital device screens

5.2 Digital typography and legibility

In order to achieve the objectives identified, the second chapter of the research explored the areas of usage of typography within the digital context followed by the usage of small digital screens. Hence the second chapter provides a comprehensive overview of the development of digital typography and its significance in various contexts, with a special focus on the role of legibility in digital typefaces. The chapter began by introducing the basic terminologies of typography and explaining the anatomy of Latin fonts, emphasizing the significance of typography in historical and modern contexts. The digitization of information and platforms was then explored, including differences between digital and print media, types of screens, encoding standards, and operating systems.

The section on digital typefaces and legibility focused on the need for legible fonts in digital media, especially on small screens. The concept of legibility was defined, and its impact on reading speed and sensory overload was discussed. The chapter emphasized the factors affecting the legibility of Latin fonts, highlighting the importance of identifying these factors. The section also provided case studies on how special fonts such as Georgia and Verdana were designed with legibility as the main factor.

Moreover, the chapter delved into the digitization of Sinhala typefaces, addressing the problems faced when not using a digitally optimized font in the context of digital platforms where the user has to interact with smaller-sized digital screens. The section discussed the evolution of the Sinhala font industry and its digitization phase, highlighting the importance of an optimized digital Sinhala font in the current typographic industry. The section provided case studies on attempts at digitizing Sinhala fonts and emphasized the potential of a digitally optimized Sinhala font for small digital screens.

In conclusion, this chapter provided a comprehensive overview of the development of digital typography and its significance in various contexts, with a special focus on the role of legibility in digital typefaces. The research emphasized the need for legible fonts on small digital screens, highlighting the significance of letter features in enhancing legibility. The rarity of Sinhala legibility research was also highlighted, emphasizing the importance of digitizing Sinhala typefaces to enhance legibility on digital platforms. Overall, this chapter serves as a foundation for the subsequent chapters of the research, which focus on identifying the specific anatomical features of Sinhala typefaces that contribute to optimizing legibility on small-scale digital device screens.

5.3 Sinhala anatomy and digital fonts

The previous chapter highlighted the importance of legible fonts on small digital screens, highlighting the significance of letter features in enhancing legibility. Hence this chapter discussed the important letter features and its anatomical structure in order to gain an understanding on how legibility can be improved by adjusting the anatomy of the letter.

This chapter focuses on understanding the skeletal structure and anatomical features of Sinhala typefaces to enhance legibility on small digital screens. The chapter introduced the concept of distinct visual features, which are derived from stroke primitives of the letter, and their impact on letter misidentification and legibility. The chapter also discussed the analysis of distinct visual features across a variety of selected sample fonts and how they affect the final anatomy of the letter.

Based on the analysis, Noto Sans Sinhala was selected for a more detailed analysis on the effects of distinct visual features on letter anatomy due to its high legibility score. The analysis of commonly misidentified letters in Noto Sans Sinhala revealed that changes in the distinct visual features of the letters can differentiate them more from each other, thus preventing similar letter misidentification and improving legibility. This chapter also identified a total set of 5 letter groups that are most commonly misunderstood due to their similarities in the anatomy. This was supported by a legibility experiment that was conducted by altering the distinct visual features of these commonly misunderstood letters.

The findings of this chapter have implications for the design of Sinhala fonts for small digital screens. By understanding the skeletal structure and distinct visual features of Sinhala letters, designers can create fonts that are optimized for legibility on small screens. This understanding can also inform the design of legibility tests and improve the accuracy of results. Overall, this chapter highlights the importance of anatomical understanding and its implications for legibility on small digital screens.

5.4 Analyzing letter misidentification as a method for optimizing legibility

Chapter 04 of this research thesis investigated the impact of distinct visual (DV) features on the legibility of Sinhala digital fonts. Highly deviating areas of letters were identified and modified at three levels of distortion through the superimposition method to understand the impact on legibility and similar letter misidentification. The experiment involved 100 Sinhala-literate students aged 23-27 who used a Short Exposure Legibility (SEL) test to assess the legibility of different typefaces, including font sizes and spacing.

The experiment found that alterations to the DV features of Sinhala letters compromised legibility, particularly when the distortion level was high. However, specific features such as the size of the DV feature, the shape of the consonant stroke, and the placement of vowel signs were found to be critical in optimizing legibility. Even small changes in the anatomic features of letters had a significant impact on legibility, highlighting the importance of considering DV features and high deviating areas when designing fonts for optimal legibility and readability.

Furthermore, the study compared Noto Sans Sinhala with Iskoola Pota, which had the lowest legibility score, to understand the impact of anatomic features on legibility. The visual analysis of Noto Sans Sinhala showed that its unique DV features were designed to reduce similar letter misidentification and increase legibility. Certain letters in Noto Sans Sinhala had distinct anatomic features, such as a vertical line and a wider horizontal bar, making them easier to distinguish from similar letters. Conversely, in Iskoola Pota, similar letters had less distinguishing visual features in their anatomy, leading to errors in reading.

Overall, the results of this chapter highlight the importance of considering anatomic features and DV features in the design and modification of Sinhala digital fonts for optimal legibility and readability. By understanding the specific features that affect legibility and similar letter misidentification, designers can make subtle changes to the curves, angles, and thicknesses of certain letters to make them more distinct from each other. This can ultimately improve the legibility of Sinhala digital fonts and enhance the conveyance of messages to readers.

5.5 Major findings

The research presented methodologies specific to Sinhala scripts for analyzing their legibility, and explored the impact of distinct visual (DV) features on legibility. The study found that anatomical changes made to DV features of Sinhala letters directly affect legibility, particularly when the distortion level is high.

The research identified DV features of letters that optimize legibility for small digital screens. Specific features such as the size of the DV feature, the shape of the primitive stroke, and the placement of DV features were found to be critical in optimizing legibility. Even small changes in the anatomic features of letters can have a significant impact on legibility, highlighting the importance of considering DV features and high deviating areas when designing fonts for optimal legibility and readability.

The study found that the legibility of a Sinhala font can be improved by reducing similar letter misidentification. Identification of similar letter sets in Sinhala was found to affect legibility. Similar letter misidentification in Sinhala fonts was found to be caused by the lack of distinction between their DV features. Hence legibility of a font was found to be improved by adjusting the DV features of most commonly misidentified letters.

Shown below in the table is the list of findings related to the most commonly misidentified letter groups and how many of participants identified their altered letter form as a percentage.

Letter Group	Superimposition	DV Feature and Alterations	Altered Letters	Percentage Identified
Group 1 ච ව ට Cha Wa Ta		Eye 3, Eye 2 Reducing the eye + eye terminal		88%
				82%
				70%
				94%
				52%
				90%
				84%

Letter Group	Superimposition	DV Feature and Alterations	Altered Letters	Percentage Identified
Group 2 ත න ක Tha Na Ka		Curve angular joint 2 Changing nose lines		78%
				93%
				96%
		Curve to Curve joint Increasing Counter Space		97%
				94%
				78%
		Curve angular joint 1 Changing nose lines		97%
				60%
				79%

Letter Group	Superimposition	DV Feature and Alterations	Altered Letters	Percentage Identified
Group 3 		Eye 2, Eye 3 Reducing the eye		96%
				76%
				78%
				75%
				63%
				64%
				82%

Letter Group	Superimposition	DV Feature and Alterations	Altered Letters	Percentage Identified
Group 4 ය ස ඝ Ya Sa Gha		Hump + Eye 2 Increasing counter Space and reducing eye terminal		94%
				91%
				84%
				55%
		Curve to curve joint + Eye 2 Increasing counter space and reducing the eye + eye terminal		96%
				88%
				76%
				63%
				93%
				79%
				96%

Letter Group	Superimposition	DV Feature and Alterations	Altered Letters	Percentage Identified
Group 5 ග හ භ Ga Ha Bha		Eye 2 Reducing eye + increasing counter space		81%
				94%
				54%
				81%
				85%
				84%
				82%
				46%
				79%
				42%
				97%

Moreover, the study compared Noto Sans Sinhala with Iskoola Pota, which had the lowest legibility score from the experiment done in Chapter 02, to understand the impact of anatomic features on legibility. The visual analysis of Noto Sans Sinhala showed that its unique DV features were designed to reduce similar letter misidentification and increase legibility. Certain letters in Noto Sans Sinhala had distinct anatomic features, such as a vertical line and a wider horizontal bar, making them easier to distinguish from similar letters. Conversely, in Iskoola Pota, similar letters had less distinguishing visual features in their anatomy, leading to errors in reading.

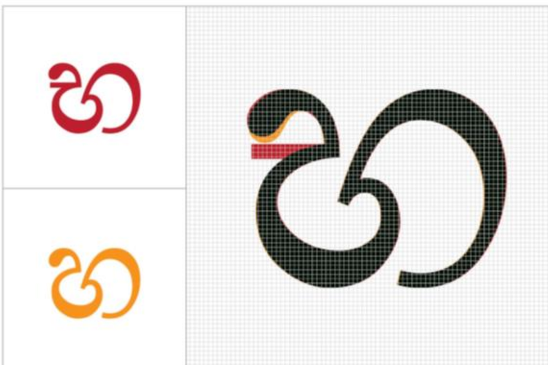


Figure 51: Left: Superimposition of letters Bha (top) and Ha (bottom) from Iskoola Pota font.
Figure 52: Right: Superimposition of letters Ha (top) and Bha (bottom) from Noto Sans font.

Overall, the results of the research highlight the importance of considering anatomic features and DV features in the design and modification of Sinhala digital fonts for optimal legibility and readability. By understanding the specific features that affect legibility and similar letter misidentification, designers can make subtle changes to the curves, angles, and thicknesses of certain letters to make them more distinct from each other. This can ultimately improve the legibility of Sinhala digital fonts and enhance the conveyance of messages to readers. The research has significant implications for the design and development of digital fonts for Sinhala and other complex scripts, emphasizing the need for more research in this area.

5.6 Limitations and future directions

There are several limitations to this research that should be considered when interpreting the results. Firstly, the study only involved a relatively small sample size of Sinhala-literate students aged 23-27, which may limit the generalizability of the findings to other populations or age groups. Additionally, the experiment used a Short Exposure Legibility (SEL) test, which may not accurately reflect real-world reading situations or long-term legibility. It would be beneficial for future research to involve a larger and more diverse sample size and to use different legibility testing methods that reflect real-world reading scenarios.

Another limitation of this study is that it focused on digital fonts only and did not investigate the impact of different printing methods on legibility. It would be interesting to examine the legibility of Sinhala letters in print media, such as books or newspapers, and to compare the results to those of digital media. Additionally, the study did not examine the impact of cultural or contextual factors on legibility. Future research could investigate the effect of different reading environments or the influence of language proficiency on legibility.

In terms of future directions, this research could be expanded to explore the impact of DV features on the readability of Sinhala fonts. While legibility focuses on the ease of identifying individual letters, readability is concerned with the comprehension of text as a whole. It would be interesting to see how modifications to DV features affect not only the legibility but also the overall readability of Sinhala fonts.

Furthermore, this research could be applied to the development of a standardized set of guidelines for the design and modification of Sinhala digital fonts. Such guidelines could be beneficial for font designers, developers, and other professionals working with Sinhala text to optimize legibility and readability. Additionally, this research could be extended to other South Asian scripts, such as Bengali, Tamil, or Devanagari, to investigate the impact of DV features on their legibility and readability.

Overall, while this research provides valuable insights into the impact of DV features on the legibility of Sinhala digital fonts, there is still much to explore in this field. Future research could address some of the limitations of this study and expand upon its findings to further improve the design and legibility of Sinhala fonts.

5.7 Practical Implications

The findings of this research have important practical implications for the design of Sinhala typefaces for small-scale digital device screens. By understanding the specific DV features that affect legibility and similar letter misidentification, designers can make subtle changes to the curves, angles, and thicknesses of certain letters to make them more distinct from each other. This can ultimately improve the legibility of Sinhala digital fonts and enhance the conveyance of messages to readers.

One of the key implications of this research is that designers should pay close attention to the size, shape, and placement of DV features in Sinhala letters. The study found that altering these features can compromise legibility, particularly when the distortion level is high. However, specific features such as the size of the DV feature, the shape of the primitive stroke, and the placement of said elements were found to be critical in optimizing legibility. Therefore, designers should carefully consider these features when designing Sinhala fonts for small-scale digital devices.

Moreover, the study highlighted the importance of designing DV features that reduce similar letter misidentification, which is a common problem in Sinhala fonts. The visual analysis of Noto Sans Sinhala showed that its unique DV features were designed to reduce similar letter misidentification and increase legibility. Certain letters in Noto Sans Sinhala had distinct anatomic features, making them easier to distinguish from similar letters. Designers should, therefore, consider implementing similar features in their typefaces to enhance legibility and reduce errors in reading on small screen digital devices.

Additionally, the findings of this research have implications for typography on digital platforms more broadly. As the use of small-scale digital devices continues to grow, designers must prioritize legibility and readability in their font designs. The results of this study can inform the design of typefaces for other scripts and languages, highlighting the importance of considering DV features and high deviating areas in font design.

In conclusion, this research provides valuable insights into the design of Sinhala typefaces for small-scale digital device screens. By taking into account the specific DV features and high deviating areas that affect legibility, designers can optimize their font designs for improved legibility and reduced errors in reading. These findings have implications not only for Sinhala typography but also for typography on digital platforms more broadly, emphasizing the importance of prioritizing legibility and readability in font design not only for small screens but in a wider context.

5.8 Conclusion and Final Remarks

In conclusion, this research has investigated the impact of distinct visual features on the legibility of Sinhala digital fonts. The study has shown that the legibility of Sinhala fonts can be significantly compromised when there are distortions in their DV features, particularly when the distortion level is high. However, specific features such as the DV features, and its positioning were found to be critical in optimizing legibility. By understanding the specific features that affect legibility and similar letter misidentification, designers can make subtle changes to the anatomy of the letters to make them more distinct from each other. This can ultimately improve the legibility of Sinhala digital fonts read in small scale digital devices and enhance the conveyance of messages to readers.

The findings of this research have practical implications for the design of Sinhala typefaces for small-scale digital device screens. Designers can utilize the information gathered in this study to optimize legibility and reduce similar letter misidentification in Sinhala fonts. By making specific changes to the DV features of letters, designers can improve the legibility of Sinhala fonts on digital platforms and ensure that they are easily readable by Sinhala-literate readers.

Overall, this research contributes to the field of Sinhala typography and legibility on digital screens by providing a deeper understanding of the specific features that impact legibility and similar letter misidentification. By utilizing this knowledge, designers can create more effective and legible Sinhala fonts for digital devices, improving the user experience and enhancing the communication of messages in Sinhala.

This research is focused mainly on general typographic knowledge. Though this research started as an exploration basically focused on the digital typographic aspect, it later evolved into a more generalized approach to typographic design, thus contributing to general typographic knowledge rather than confined into the digital space.

As a final remark, this thesis has contributed to the field of Sinhala typography by investigating the impact of distinct visual features on the legibility of Sinhala digital fonts. The study has identified specific features that affect legibility and similar letter misidentification, highlighting the importance of considering anatomic features and DV features in the design and modification of Sinhala digital fonts. The findings provide practical implications for designers to make subtle changes to optimize the legibility of Sinhala fonts for small digital screens, ultimately enhancing the conveyance of messages to readers. This research serves as a foundation for further investigation and improvement in Sinhala typography, addressing the growing demand for digital content in the Sinhala language.

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