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Enhancing accessibility of Thai government mobile applications through effective use of typefaces, type sizes, and colour contrast: A technical review

ABSTRACT

This study reviewed the legibility of Thai typefaces, type sizes, and colour contrast in mobile applications provided by Thai government offices. Although the Electronic Government Agency (Public Organization) (EGA) has introduced the Government Website Standards and Government Mobile Application Standards, these standards need to cover the design of Thai typographical concerns such as legibility and visibility in great detail. This study aimed to identify typographical issues that may arise in these mobile applications and gain a deeper understanding of the subject matter. The findings of this study could lead to future investigations that provide a better understanding of the topic and contribute to the development of appropriate standards and legislation. We conducted an in-depth analysis of Thai Government mobile applications on Android focusing on public service areas. Using a smartphone to take screenshots and a vector graphics design program to measure physical type sizes based on the Bo Baimai height measurement, we measured the use of typefaces, type sizes, and colour contrast to ensure accessibility to all users. Additionally, we used a colour contrast analyser application to measure colour contrast and ensure accessibility to all users. Our study provides insights to improve user experiences with these applications and highlights that Thai web and mobile standards lack suitable fonts and sizes. We identified two main categories of Thai typefaces: conventional text fonts and Roman-like Thai fonts. Most Thai mobile applications used letter sizes bigger than 1.2 mm in Bo Baimai height, but some used smaller sizes, which could be worse for reading. The smallest type sizes for body text ranged from 1 to 1.7 mm. Regarding contrast ratios, we found that regular text in selected mobile applications did not meet the Web Content Accessibility Guidelines (WCAG) 2.1 enhanced contrast requirement of a 7:1 ratio. However, some contrast ratios for large text met the 4.5:1 requirement. Some regular text with a 4.5:1 contrast ratio requirement passed the WCAG 2.1 minimum contrast test, whereas some large text with a 3:1 contrast ratio requirement also met the criteria. Our study suggests the need for developing better standards and regulations for Thai fonts, sizes, and colour contrasts in mobile applications to ensure accessibility for all users.

KEY WORDS

accessible typography, Thai typeface, font size, colour contrast, mobile application

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Background

Mobile applications have become indispensable to our lives, offering unprecedented convenience and efficiency. From communication to entertainment, shopping to banking, mobile applications have transformed how we access information and services. These applications have revolutionised the way we communicate, enabling us to stay connected with our loved ones through messaging applications, irrespective of our location. Moreover, mobile applications have significantly impacted education, providing students with interactive and engaging learning experiences that enhance their skills and knowledge.

Mobile applications have also expanded to the public sector, including government services, providing citizens with fast and efficient access to government services and information. Mobile government applications have transformed how citizens interact with their government, empowering them to participate in civic engagement and decision-making processes. These applications have enabled citizens to pay taxes, renew licenses, report issues, access public records, and receive alerts and notifications from their government.

Furthermore, mobile government applications have enhanced the quality of government services, enabling government agencies to respond promptly to citizens' needs and efficiently manage public resources. They have also increased transparency and accountability, allowing citizens to monitor government activities and hold public officials accountable. Mobile government applications have contributed significantly to the digital transformation of government services, making them more efficient, accessible, and citizen-centric.

Although the Thai government has taken steps to encourage universal design policies (Office of the National Economic and Social Development Council, 2016, p.148), more focus still needs to be on inclusive typography principles. Although universal design is a multidisciplinary approach, architectural and environmental design have been given more attention than other design disciplines. After reviewing guidelines from Thai government departments and organisations and research from experts, including the Department of Packaging and Materials Technology, Faculty of Agro-Industry, Kasetsart University (n.d.), National Office for Empowerment of Persons with Disabilities (n.d.), Office of the Higher Education Commission (2013), Office of Transport and Traffic Policy and Planning (2015), The Association of Siamese Architects Under Royal Patronage (2014) and research by Sawangjaroen, Emphandhu & Kulachol (2017), it was found that there should be more specific principles for inclusive design regarding Thai typography because the current guidelines are outdated and based on old general principles or foreign research.

There is a need to pay more attention to the importance of inclusive design and self-knowledge expansion in this area.

Regarding typography, legibility and readability are crucial factors to consider. After all, only some have perfect eyesight, whether they wear glasses or not. This is why typographers must consider reading efficacy when choosing letterforms or typefaces. The legibility of a font can significantly affect how easy it is to read (Noel, 2015; Slattery & Rayners, 2009), which is why it is so important to invest time and resources into the development of typography in every language.

Unfortunately, the legibility of fonts has not been extensively researched in Thailand, which poses a challenge for visually impaired individuals and the ageing population. More data is needed to recommend optimal Thai letterforms suitable for low-vision or general readers. Although some scientific studies have examined Thai letterforms (Rattanakasamsuk, 2013; Teeravarunyou & Laosirihongthong, 2003; Waleetorncheepsawat et al., 2012), they have yet to discuss or suggest design practices for improving legibility. These studies have evaluated which typeface or type size was more legible but have yet to provide in-depth explanations of aspects of letterforms that influence recognition under tested conditions.

When it comes to design, the focus should always be on the people interacting with the product. It is about creating something that looks good and ensuring that it meets the user's needs and elicits a positive response (Frascara, 2015). One crucial aspect of communication design is inclusive typography, which can help visually impaired individuals continue reading even when their visual acuity is low (Ompteda, 2009). By incorporating principles of inclusive typography, designers can create accessible products for a broader range of people.

Awan et al. (2021) have identified several barriers to smartphone application usage, categorised into five distinct categories: sensory function, cognition, motor skills/impairment, mental model, and financial limitation. According to their research, sensory function-related issues, such as small font size, screen size, font type, buttons, and colour contrast, were found to be the most commonly reported barriers to the usability of web and smartphone applications. Awan et al. (2021) also discovered that these sensory function-related issues had the highest critical value among the identified barriers.

Typefaces are an essential aspect of mobile application design. It is an important decision because it guarantees users can easily read the text on their devices. Furthermore, the type sizes are uniform and well-suited throughout the applications, making them simple to navigate. Colour contrast is also a crucial factor to consider when designing mobile applications.

Using contrasting colours guarantees that vital components such as buttons, headings, and text are noticeable on the screen. This enhances usability and ensures that users can rapidly and effortlessly locate the required information.

According to Serra et al. (2015), it is of utmost importance to evaluate the accessibility of mobile applications in e-government and m-government to identify accessibility issues that require immediate attention. Established methods of evaluations in the field of Human-Computer Interaction, such as tests with target users or accessibility audits conducted by experts using heuristics or guidelines, can be employed for performing accessibility evaluations (Serra et al., 2015).

Despite the fact that accessibility audits with guidelines can only address some of the challenges that disabled users may face (Power et al., 2012), they remain valuable in identifying common issues that can be avoided (Serra et al., 2015). The insights gained from these evaluations can help to improve the accessibility of mobile applications, which is crucial for creating inclusive technology.

According to WCAG 2.1 Understanding Docs, in minimum contrast (AA), text (including image of text) has a contrast ratio of at least 4.5:1 for regular-size text and at least 3:1 for large-scale text (at least 18 points/24 pixels or bold and at least 14 points/18.5 pixels) unless the text is purely decorative (World Wide Web Consortium: W3C, 2016a; World Wide Web Consortium: W3C, 2022a; World Wide Web Consortium: W3C, 2023a). For enhanced contrast (AAA), text (including image of text) has a contrast ratio of at least 7:1 for regular-sized text and at least 4.5:1 for large-scale text (at least 18 points/24 pixels or bold and at least 14 points/18.5 pixels) unless the text is purely decorative (World Wide Web Consortium: W3C, 2016b; World Wide Web Consortium: W3C, 2022b; World Wide Web Consortium: W3C, 2023b).

Despite the efforts made by the Electronic Government Agency (Public Organization) (EGA), Thailand has introduced the Government Website Standards (EGA, 2012; EGA, n.d.) and Government Mobile Application Standards (EGA, 2015).

However, these standards need to cover the design of Thai typographical concerns such as legibility and visibility in great detail. Further attention should be given to this aspect to ensure an optimal user experience for Thai readers.

For this reason, the current study aimed to reveal and review issues with Thai typefaces, focusing on typeface classifications, type sizes, and colour contrast used in Thai government mobile applications. This study will contribute to an awareness of the problems that may inspire future studies of the development of Thai government mobile applications based on positive typographic design.

Method

When evaluating the accessibility of mobile applications, two primary methods are generally accepted.

The first method involves assessing the application against a checklist of accessibility guidelines through either manual inspection by accessibility experts (Nielsen, 1993; Nugroho, Santosa & Hartanto, 2022; Serra et al., 2015) or by using automated tools (Ross et al., 2020; Silva, Eler & Fraser, 2018). This method can be complemented by using disability simulation software (Choo, Balan & Lee, 2019). However, it should be noted that such simulations may produce only partially accurate results (Tigwell, 2021).

The second method involves user-centred evaluation, where end-users test the software (Grellmann et al., 2018; Nugroho, Santosa & Hartanto, 2022).

Arias et al. (2022) have proposed an approach that involves examining user reviews to determine the accessibility status of applications. User reviews can be valuable in revealing how accessible the application is perceived to be by end-users.

Eler et al. (2018) identified two approaches to performing mobile accessibility testing: manual testing and automated tools. Manual testing involves meticulously exploring and inspecting the application, as well as checking every user interface component. Google offers two practical tools for this purpose- the UI Automator (Google for Developers, 2024a) and the Accessibility Scanner (Google, 2024; Google Play, 2023). However, the manual approach may need to be more efficient for larger applications or frequent testing. In such cases, developers may rely on tools like Lint (Google for Developers, 2024b), Espresso (Google for Developers, 2024c), and Robolectric (Robolectric, 2023) to partially automate accessibility testing tasks. While Lint can only scrutinise static properties that stem from the source code, testing frameworks such as Espresso and Robolectric can dynamically examine accessibility properties during test execution. Notably, comparable tools exist for iOS, such as Earl-Grey (GitHub, 2024a) and KIF (GitHub, 2024b).

The current study focused on identifying and examining issues regarding Thai typefaces, specifically typeface classifications, type sizes, and colour contrast used in Thai government mobile applications. The study aimed to raise awareness about the problems that might need a more in-depth investigation in future research. To achieve this, simple technical methods were employed to determine type sizes and colour contrast in the Thai government mobile applications. While this approach may require more time and attention to detail than automated tools, it could provide valuable insights that will be useful in addressing the identified issues.

Survey for Thai Government Mobile Applications

The present study focused on the Thai government mobile applications available on Android. We carefully selected a range of applications covering public service areas such as health care, taxes, essential utilities, and more. Our sample of applications was compiled from the offices of the Thai government, and we have provided a detailed overview in Figure 1 and Table 1.

These applications are readily accessible to the public, and we believe they can offer valuable and convenient resources to Thai citizens.

Measurement of Type Sizes on Thai Government Mobile Applications

We took screenshots of each selected mobile application's user interface (UI) using a smartphone (Infinix Zero 5G 2023) to measure the physical type sizes used on Thai government mobile applications.

This smartphone has a resolution of 1080 x 2460 pixels and is displayed on a screen diagonal of 6.78 inches, with a screen width of 2.7300 inches and a screen height of 6.2158 inches. This screen size of 6.78 inches is considered to have a large screen (Samsung, 2024).

We set the font size on the screen display to the largest option. After taking the screenshots, we imported them into Adobe Illustrator 2021. We resized them from 1080 x 2460 pixels to 196.560 x 447.538 pixels so that the sizes of the resized images would conform to the physical screen size of 2.7300 x 6.2158 inches.

Various studies included in this review provided recommendations for font size, with inconsistent use of metric systems. However, the most common metric used was "points." For instance, in their studies, Chatrangsan & Petrie (2019), Darroch et al. (2005), Hou et al. (2020), Kong et al. (2011), Lege et al. (2013), Wang et al. (2009), Yeh (2015), Yeh (2020), and Ziefle (2010) all employed points as their unit of measurement for font size.

Other studies used pixels (Hou et al., 2020; Wang et al., 2009), millimetres (Fujikake et al., 2007; Hasegawa et al., 2009; Hou et al., 2020; Punsongserm, 2019; Punsongserm, 2020; Punsongserm, Sunaga & Ihara, 2017a; Punsongserm, Sunaga & Ihara, 2017b; Punsongserm, Sunaga & Ihara, 2018a; Punsongserm, Sunaga & Ihara, 2018b), or arcminutes of visual angle (Hasegawa et al., 2009; Punsongerm, 2023; Punsongserm & Suvakunta, 2022a; Punsongserm & Suvakunta, 2022b) to indicate font size.

To ensure inclusive communication with a diverse range of readers across various fields, we recommend utilising all metric systems with conversions for font size.

» **Figure 1:** *Examples of selected Thai government mobile applications*

The point size measurement is typically used to determine the font size unit of a typographic design.

However, it is essential to note that different typefaces composed in the same point size can affect the size of the x-height. According to Legge & Bigelow (2011, p.19), measures of x-height provide a convenient metric that is familiar to both typographers and vision researchers.

Similarly, Punsongserm, Sunaga & Ihara (2017a) used Bo Baimai height measurements to define Thai-type sizes in their study. This method provides normalisation by the character's height / บ/ (Bo Baimai) and accurately regulates the equalisation of character heights within any font.

As a result, we have also adopted the Bo Baimai height measurement (Punsongserm, 2019; Punsongserm, 2020; Punsongserm, Sunaga & Ihara, 2017a; Punsongserm, Sunaga & Ihara, 2017b; Punsongserm, Sunaga & Ihara, 2018a; Punsongserm, Sunaga & Ihara, 2018b; Punsongserm & Suvakunta, 2022a; Punsongserm & Suvakunta, 2022b) in millimetres and pixels to measure the physical type sizes used on Thai government mobile applications.

Table 1

List of selected Thai government mobile applications

No.	Application Name	Category	Provider
1	ทางรัฐ (Thang rath) Version 2.5.0	Government Services	Digital Government Development Agency, Thailand (https://play.google.com/store/apps/details?id=th.or.dga.citizenportal)
2	ThaID Version 2.4.0	Government Services	The Bureau of Registration Administration (https://play.google.com/store/apps/details?id=th.go.dopa.bora.dims.ddopa)
3	RDU รู้เรื่องยา Version 1.5.9	Medicine	Digital Government Development Agency, Thailand (https://play.google.com/store/apps/details?id=com.uhosnet)
4	Clicknic Version 3.4.14	Medical Services	Clicknic Institute of Disease Prevention and Control (SorBor-Mor.), Office of Health Promotion Fund (SorSor.) Thammasat University Chalermprakiet Hospital (https://play.google.com/store/apps/details?id=co.clicknic.clicknicandroid)
5	หมอพร้อม (Mor Prom) Version 1.2.1	Medical Services	Ministry of Public Health (https://play.google.com/store/apps/details?id=com.mor.promplus)
6	สมุดสุขภาพผู้สูงอายุ (Bluebook) Version 2.8.2	Health Care	Department of Health (Thailand) (https://play.google.com/store/apps/details?id=com.moph.anamai.bluebook)
7	สมุดสุขภาพ (Smud Sukhaphap) Version 2.0.0	Health Care	Department of Health (Thailand) (https://play.google.com/store/apps/details?id=th.go.moph.anamai.healthbook)
8	MyMo by GSB Version 2.15.0	Finance & Bank	Government Savings Bank (https://play.google.com/store/apps/details?id=com.mobilife.gsb.mymo)
9	เป๋าตัง (Paotang) Version 12.4.1	Finance & Utility	Krungthai Bank PCL. (https://play.google.com/store/apps/details?id=com.ktb.customer.qr)
10	RD Smart Tax Version 3.3.0	Revenue	The Revenue Department (https://play.google.com/store/apps/details?id=com.revenuedepartment.app)
11	ภาษีไปไหน (Phasi Pai Nai) Version 2.3.2	Government Spending	Digital Government Development Agency, Thailand (https://play.google.com/store/apps/details?id=th.or.ega.spending)
12	PDMO Version 2.7.6	Public Debt	Public Debt Management Office (https://play.google.com/store/apps/details?id=com.zealtech.pdmo)
13	PEA Smart Plus Version 3.2.11	Public Utility: Electricity Authority	Provincial Electricity Authority (https://play.google.com/store/apps/details?id=com.esrith.pea_mobile)
14	PWA Plus Life Version 3.5.2	Public Utility: Water Supply	Provincial Waterworks Authority (https://play.google.com/store/apps/details?id=th.co.pwa.pwamobile)

In the field of vision science, Swearer (2018) postulated that visual angle is an essential metric that plays a significant role in indicating the size of visual stimuli without explicitly stating their distance or size. Additionally, the visual angle can be used to express intraocular dimensions, predict the space an image will subtend on the retina, and describe the relative location of separate retinal images. Moreover, the visual angle is employed to specify the size of spatial frequency gratings. The visual angle, as Swearer (2018) explains, originates from incoming light rays at the nodal point of the eye and is dependent on multiple factors, such as the size of the stimulus, its distance from the observer, and whether or not it is viewed in the frontal plane. In a simplified model, the visual angle is formed from the light rays from two points of a viewed object, in height, width, or depth, as they enter the eye and is proportional to the angle projected onto the retina. Consequently, the subtended image's size is determined by the visual angle. When an object is viewed at different distances, it will have different retinal sizes, as similarly sized objects viewed at different distances.

De Valois & De Valois (1988) and O'Shea (1991) discovered that objects of varying sizes can appear to have the same visual angle if they are situated at appropriate distances from the observer. This phenomenon has significant implications for visual perception and must be taken into account when designing and conducting experiments in the field of visual cognition.

According to Swearer (2018), the expression of visual angle subunits is measured in minutes and seconds of arc. A degree is equivalent to 60 arcmin, and an arcmin is equivalent to 60 arcsec. In calculating visual angle (θ), the geometrical formulas are crucial in relating visual angle, size, and distance. These formulas are based on the size of the stimulus object (S0) at a specified viewing distance (D0), among other factors. Additionally, the retinal image size (Si) is dependent on an average image distance (Di) of 17 mm from the lens of the eye to the retina. As stated by Swearer (2018), the calculation for visual angle is expressed as $\theta = 2 \arctan(S0/2D0)$. However, for visual angles smaller than 10°, the calculation can be simplified to $\theta = \arctan(S0/D0)$.

As part of the present study, we have not only conducted measurements of physical sizes (Bo Baimai height) of type sizes across various Thai government mobile applications but have also calculated the visual angles that would be perceived based on these measurements. To maintain consistency and accuracy, we defined the viewing distance as 40 cm, which aligns with the traditional near point for optometric examinations and is a typical reading distance for paper media (Boccardo, 2021).

Figure 2 presents the formula for calculating the visual angle of Thai letterforms, accompanied by a practical example. Assuming that we have to compute the visual angle for Bo Baimai with a height of 1.5 mm and a viewing distance of 40 cm (400 mm), we can apply the specified values in the formula (Step 1). This would lead us to the computation of $2 \cdot \arctan(0.001875)$ (Step 2). The arctan of 0.001875 is equivalent to 0.10742946069325° (Step 3). Consequently, we can discern that the visual angle of Bo Baimai's height of 1.5 mm, viewed from a distance of 40 cm, is 0.2149° (Step 4).

$$\text{Visual Angle} = 2 \cdot \arctan\left(\frac{\frac{\text{Bo Baimai height}}{2}}{\text{Viewing Distance}}\right)$$

(1) $$2 \cdot \arctan\left(\frac{\frac{1.5}{2}}{400}\right)$$

(2) $$2 \cdot \arctan\left(0.001875\right)$$

(3) $$2 \times 0.10742946069325$$

(4) $$0.2149$$

» **Figure 2:** *Formula and examples for Thai letterforms' visual angle calculation*

Measurement of Colour Contrast on Thai Government Mobile Applications

Numerous tools are available that can assist in checking colour contrast on digital screens. These applications are readily accessible via web browsers. Prominent examples include the Color Contrast Checker developed by the Institute for Disability Research, Policy, and Practice (WebAIM, 2024), the Contrast Checker by Adobe (Adobe, 2024), and the APCA Contrast Calculator by Myndex Research (Myndex, 2024).

Alternatively, individual contrast checker tools can be installed on Windows and Mac operating systems, such as the Colour Contrast Analyzer (CCA) provided by TPGi (TPGi, 2023). Additionally, mobile contrast checker tools are also accessible. The A11Y: Audit + Color Contrast app by Accessible Resources Ltd (Accessible Resources, 2024) and the Accessibility Scanner app by Google (Google Play, 2023) can be employed for this purpose. These applications mentioned above are designed to comply with the feature compliance indicators for WCAG.

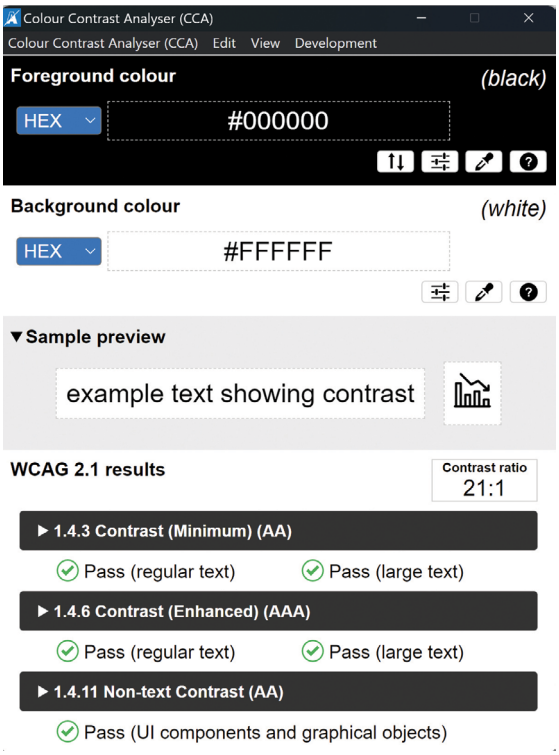
In our current study, we utilised the CCA version 3.2.1 developed by TPGi (TPGi, 2023) to measure the colour contrast of screenshots of selected Thai government mobile applications (as seen in Figure 3). This application is designed to meet the feature compliance indicators for WCAG 2.1 (World Wide Web Consortium: W3C, 2018), which is crucial for ensuring accessibility to all users. As a part of our analysis, we used this application to assess the colour contrast of foregrounds (texts) and backgrounds on selected Thai government mobile applications that were imported into Adobe Illustrator 2021 after the procedure of type size measurement was completed (see the previous topic).

To provide a brief and precise summary of the research conducted, we have incorporated a diagram in Figure 4. This diagram encapsulates an array of activities that were carried out during the study

Results and Discussion

According to Table 1, some Thai government mobile applications are equipped with a feature that prevents users from taking screenshots. After examining the data, we have identified four such applications that offer this protection: ThaID, หมอพร้อม (Mor Prom), MyMo by GSB, and เป๋าตัง (Paotang).

This is an essential feature for those concerned about privacy and security while using these applications. It is reassuring that these applications are taking steps to protect their users this way; however, we could not measure these mobile applications' type sizes and colour contrasts.



» **Figure 3:** *User interface of CCA version 3.2.1*

Regulations and Standards

In accordance with Strategy 6, Stratagem 6.5 of the Information and Communication Technology Policy Framework 2011–2020, fostering online learning communities and promoting solid social integration is imperative. The EGA has established the Government Mobile Application Standard Version 1.0 to comply with the government's framework.

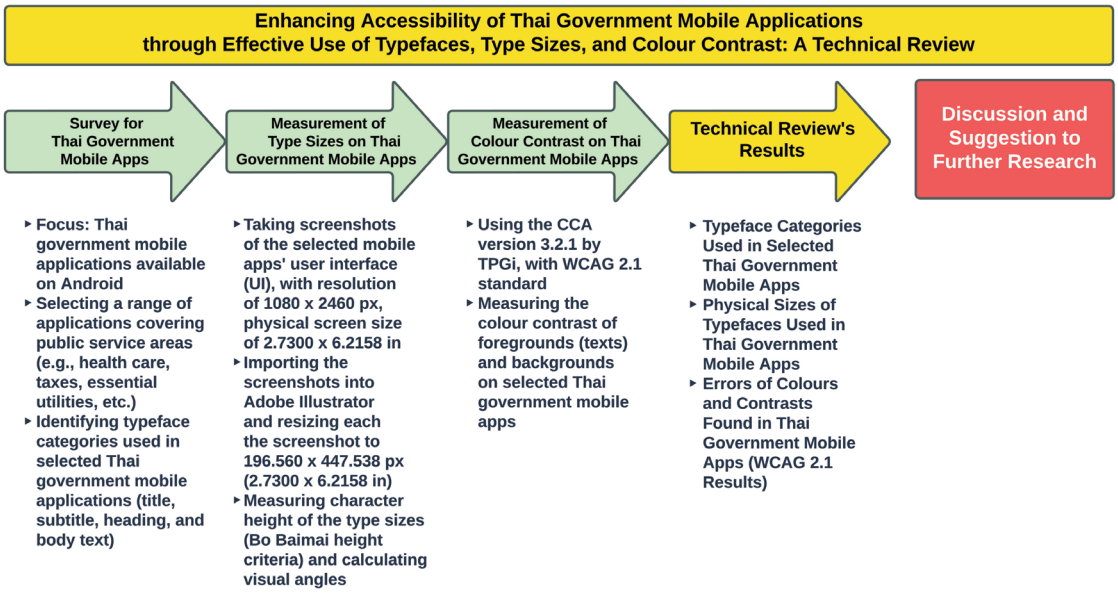
This standard ensures that mobile application development meets technical standards and requirements, including personal data protection and security protocols (EGA, 2015). However, it is important to note that the Thai Government Mobile Application Standard does not recommend appropriate Thai typefaces and sizes for application users.

Use of Typefaces, Type Sizes, and Colour Contrast on Thai Government Mobile Applications

Typefaces

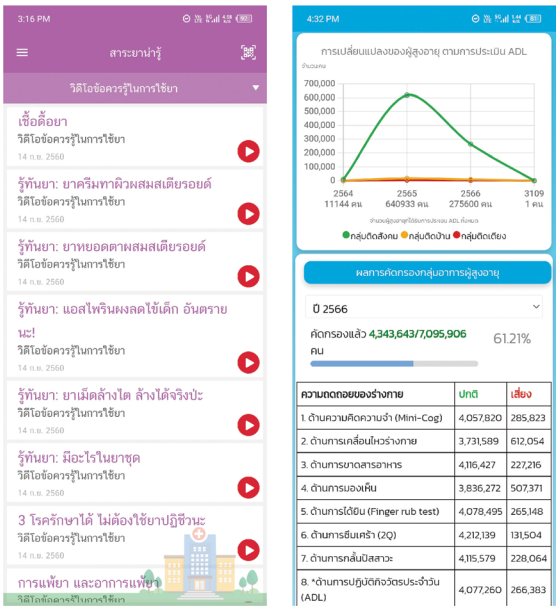
After conducting our initial survey of Thai government mobile applications, we delved deeper into the fonts used in these applications. Our analysis revealed two main categories of Thai typefaces: Thai conventional text fonts and Roman-like Thai fonts, as depicted in Figure 5. To illustrate our findings further, we compiled a table (Table 2) that showcases the typefaces used in each selected Thai government mobile application.

Table 2 shows that the ทางรัฐ (Thang Rath) application is the only one to have used a Thai conventional text typeface exclusively for words and texts. In contrast, the สมุดสุขภาพผู้สูงอายุ (Bluebook), สมุดสุขภาพ (Smud Sukhaphap), RD Smart Tax, and PEA Smart Plus applications have used Roman-like Thai typefaces. Some other applications have mixed two typeface categories for their words and texts. It is important to note that no regulations or standards in Thailand dictate the proper typeface for screens or mobile devices. However, Thai conventional text fonts are crafted with expert precision, featuring distinct letter elements that make them easily identifiable to readers. These elements, such as the line,



» **Figure 4:** *Activities conducted in the present study*

first loop, tail, second loop, foot, beak, limb, and core, are meticulously designed, as Punsongserm, Sunaga & Ihara (2017a) pointed out. In contrast, Thai fonts that resemble Roman or Latin letterforms often overlook or ignore these unique features, according to Punsongserm, Sunaga & Ihara (2018c). This contrast underscores the importance of selecting the right font for effective communication in the Thai language, ensuring that all readers can easily understand and comprehend the content.



» **Figure 5:** *Examples of typefaces used in selected Thai government mobile applications*

Note
Left: Thai conventional text fonts displayed in the RDU รู้เรื่องยา application.
Right: Roman-like Thai fonts displayed in the สมุดสุขภาพผู้สูงอายุ (Bluebook) application.

In a study on Thai fonts conducted by Kamollimsakul, Petrie & Power (2014a), using a conservative font, a Thai conventional text font, is more efficient and leads to quicker reading on web pages than a modern font, a Roman-like Thai font. Interestingly, both younger and older adults preferred conservative fonts over modern ones. Later, Punsongserm, Sunaga & Ihara (2018c) analysed the legibility and visibility of general words using two methodologies. The study included ten fonts commonly used in Thailand, including five conventional and five Roman-like Thai fonts. The findings showed that Thai conventional fonts were more readable than Roman-like Thai fonts, and readers had fewer errors in identifying single words and word strings, especially in low-illumination environments. In particular, using Roman-like Thai fonts resulted in significantly more misread words than Thai conventional fonts. These results suggest that when it comes to legibility and visibility, Thai conventional fonts are a better choice than Roman-like Thai fonts.

Furthermore, a recent study by Punsongserm & Suvakunta (2022a) found that using Thai conventional text fonts enhanced the readers reading Thai conventional fonts in less time than Roman-like fonts. The study revealed that readers of all ages had an easier time reading drug labels with Thai conventional text fonts, especially Thai UD font.

Table 2
Checklist of typefaces used in selected Thai government mobile applications

No.	Application Name	Used Typeface			
		Conventional Text Typeface		Roman-Like Thai Typeface	
		Title, Subtitle, Heading	Body	Title, Subtitle, Heading	Body
1	ทางรัฐ (Thang Rath) Version 2.5.0	●	●	-	-
2	RDU รู้เรื่องยา Version 1.5.9	●	●	●	●
3	Clicknic Version 3.4.14	●	●	●	●
4	สมุดสุขภาพผู้สูงอายุ (Bluebook) Version 2.8.2	-	-	●	●
5	สมุดสุขภาพ (Smud Sukhaphap) Version 2.0.0	-	-	●	●
6	RD Smart Tax Version 3.3.0	-	-	●	●
7	ภาษีไปไหน (Phasi Pai Nai) Version 2.3.2	●	●	●	●
8	PDMO Version 2.7.6	●	●	●	●
9	PEA Smart Plus Version 3.2.11	-	-	●	●
10	PWA Plus Life Version 3.5.2	●	●	●	●

Interestingly, the study also showed significant differences in reading times between younger and older participants, with younger participants having faster reading times and older participants having slower reading times.

These findings underline the importance of using easily readable fonts, especially for crucial information such as drug labels. Moreover, a further study by Punsongserm & Suvakunta (2022b) indicated that conventional text typefaces with distinctive key letter features have a lower misreading in word accuracy compared to Roman-like Thai fonts when reading drug label contents.

Type Sizes

After conducting an in-depth study on the mobile applications developed by the Thai government, we analysed the size of the letters displayed. Our research used millimetre and pixel units to measure the characters' sizes. We discovered that the smallest text size used in the selected Thai government mobile applications was approximately 0.6420 mm (1.8198 px) in Bo Baimai height (PWA Plus Life application).

Table 3 presents the physical sizes and visual angles of typefaces used in the selected mobile applications.

Based on the study conducted on mobile applications such as ทางรัฐ (Thang Rath), RDU รู้เรื่องยา, Clicknic, ภาษีไปไหน (Phasi Pai Nai), PDMO, and RD Smart Tax, the current study found that most of these applications tend to use letter sizes bigger than 1.2 mm in Bo Baimai height for words, phrases, and short sentences (Tables 3).

However, some applications like สมุดสุขภาพผู้สูงอายุ (Bluebook), สมุดสุขภาพ (Smud Sukhaphap), PEA Smart Plus, and PWA Plus Life used smaller font sizes of 1 mm or less, as shown in Tables 3. It is important to note that font size can affect the user experience, so choosing a type size that is easy to read for all users is necessary. Furthermore, for body text, the smallest type sizes used ranged from 1 to 1.7 mm in applications like RDU รู้เรื่องยา, Clicknic, RD Smart Tax, and ภาษีไปไหน (Phasi Pai Nai).

The objects we see depend on distance. Several studies have looked into the viewing distances of young adults while reading a smartphone.

Table 3

Physical sizes and visual angles of typefaces used in Thai government mobile applications

No.	Application Name	Type Size (Bo Baimai Height)							
		Title, Subtitle, Heading				Body			
			Millimeter	Pixel	Degree (°) (Viewing Distance = 400 mm)		Millimeter	Pixel	Degree (°) (Viewing Distance = 400 mm)
1	ทางรัฐ (Thang Rath) Version 2.5.0	Min	1.2860	3.6454	0.1842				
		Max	2.4350	6.9024	0.3488				
2	RDU รู้เรื่องยา Version 1.5.9	Min	1.2870	3.6479	0.1843	Min	1.0280	2.9128	0.1473
		Max	2.2320	6.3265	0.3197	Max	2.2430	6.3593	0.3213
3	Clicknic Version 3.4.14	Min	1.2220	3.4636	0.1750	Min	1.6670	4.7254	0.2388
		Max	3.0170	8.5519	0.4322	Max	1.9260	5.4595	0.2759°
4	สมุดสุขภาพผู้สูงอายุ (Bluebook) Version 2.8.2	Min	8.3500	2.3659	0.1196				
		Max	2.4260	6.8761	0.3475				
5	สมุดสุขภาพ (Smud Sukhaphap) Version 2.0.0	Min	1.0250	2.9061	0.1468				
		Max	4.6280	131.188	0.6629				
6	RD Smart Tax Version 3.3.0	Min	1.4130	4.1952	0.2024	Min	1.3480	3.8211	0.1931
		Max	2.3100	6.5480	0.3309	Max	1.6050	4.5496	0.2299
7	ภาษีไปไหน (Phasi Pai Nai) Version 2.3.2	Min	1.2850	3.6435	0.1841		1.6690	4.7310	0.2391
		Max	2.5020	7.0923	0.3584				
8	PDMO Version 2.7.6	Min	1.2860	3.6454	0.1842				
		Max	3.9150	11.0984	0.5608				
9	PEA Smart Plus Version 3.2.11	Min	1.0330	2.9268	0.1480				
		Max	3.5300	10.005	0.5056				
10	PWA Plus Life Version 3.5.2	Min	6.4200	1.8198	0.0920				
		Max	2.9500	8.3631	0.4226				

Long et al. (2017) found that the mean viewing distance over 60 minutes was 29.2 ± 7.3 cm, with the viewing distance being significantly more significant during the first, second, and fifth 10-minute periods than during the final 10-minute period. Yoshimura et al. (2017) reported that the viewing distance of smartphones in a sitting position ranged from 13.3 to 32.9 cm among participants, whereas in the lying position, it ranged from 9.9 to 21.3 cm.

In addition, Panke et al. (2019) found that the viewing distance for digital active tasks was found to be shorter (29.3 ± 4.7 cm) compared to passive tasks (32.3 ± 6.0 cm). Additionally, the study found that the viewing distance for digital passive tasks was shorter (32.3 ± 6.0 cm) compared to hardcopy passive tasks (34.4 ± 5.9 cm). Finally, Boccardo (2021) examined viewing distance in presbyopic and nonpresbyopic age groups and found that the average viewing distance was 36.1 ± 7.2 cm while sitting and 37.4 ± 6.8 cm while standing. It is important to note that the average viewing distance differed among genders and age groups.

It is essential to consider the appropriate type size when designing materials to be viewed by both young and older adults. According to Santayayon, Pipitpukdee & Phantachat (2011), the minimum Thai type size recommended for a viewing distance of 50 cm is 2 mm, corresponding to a visual angle of 0.2292°. However, if the viewing distance were to decrease to 45 cm, 40 cm, 35 cm, 30 cm, 25 cm, 20 cm, 15 cm, or 10 cm, the corresponding visual angles would be 0.2546°, 0.2865°, 0.3274°, 0.3820°, 0.4584°, 0.5730°, 0.7639°, and 1.1459°, respectively. It is important to remember these conversions when designing materials to ensure they are easily viewable for all intended audiences.

A drug label study conducted by Punsongserm & Suvakunta (2022a) suggested that the optimal range of type sizes for easy readability among readers of diverse backgrounds may be between 1.3 and 2 mm in Bo Baimai height for reading body text. The study further recommended using larger sizes for headlines, subheads, and text typed with Roman-like Thai typefaces.

From this, it can be safely assumed that using letter sizes larger than 1.3 mm in Bo Baimai height can be highly effective for screen-based reading for readers. However, it is crucial to remember that the effectiveness of reading also relies on the category of typefaces, thickness stroke, letter spacing, and other factors. To improve mobile application standards or guidelines, it is essential to conduct further research to validate our assumptions.

At type size of 1.3 mm in Bo Baimai height, the viewing distance of 50 cm, 45 cm, 40 cm, 35 cm, 30 cm, 25 cm, 20 cm, 15 cm, or 10 cm, the corresponding visual angles would be 0.1490°, 0.1655°, 0.1862°, 0.2128°, 0.2483°, 0.2979°, 0.3724°, 0.4966°, and 0.7448°, respectively.

Regarding optometric examinations, the traditional near point is typically 40 cm (Boccardo, 2021). This distance is commonly used for reading paper media. It corresponds to a visual angle of 0.1862° at a minimum type size of 1.3 mm in Bo Baimai height. However, recent smartphone viewing distance studies suggested that the mean viewing distance over 60 minutes is 29.2 cm (Long et al., 2017), with a corresponding visual angle of 0.2551°. Additionally, when using smartphones in a sitting or lying position, the farthest viewing distance is typically 32.9 cm or 21.3 cm (Yoshimura et al., 2017), with corresponding visual angles of 0.2264° and 0.3497°, respectively. It is also worth noting that the average viewing distance for presbyopic and nonpresbyopic age groups is around 36–37 cm when sitting or standing (Boccardo, 2021), with corresponding visual angles of 0.2063° and 0.1992°, respectively. These visual angles are similar to those described in Santayayon, Pipitpukdee & Phantachat (2011) (i.e., a visual angle of 0.2292°).

Lastly, Punsongserm & Suvakunta (2022b) recommended a minimum Thai type size of 1.3–2 mm Bo Baimai height for reading body text at viewing distances that provide visual angles exceeding 0.200° to assure legibility for readers.

Following the WCAG 2.1 Understanding Docs guidelines (World Wide Web Consortium: W3C, 2022a; World Wide Web Consortium: W3C, 2022b) is essential for text and image contrast. This means that regular-sized text should have a contrast ratio of at least 4.5:1. In contrast, the larger text should have a ratio of at least 3:1 (at least 18 points/24 pixels or bold and at least 14 points/18.5 pixels). To better understand what this means in terms of typeface, we can look at the cap height and x-height of typefaces like Times New Roman, Arial, Helvetica, and Univers. For example, at 14-point size, the cap height of these typefaces ranges from 3.270 to 3.566 mm, whereas the x-height ranges from 2.209 to 2.583 mm (Punsongserm & Suvakunta, 2022b).

Furthermore, we measured and found that at an 18-point size, the cap height ranges from 4.204 to 4.585 mm, whereas the x-height ranges from 2.841 to 3.321 mm. By keeping these measurements in mind, we can ensure that our text is easily readable and accessible to all users.

A study conducted by Kamollimsakul, Petrie & Power (2014a) found that both younger and older adults showed a preference for the conservative font type (Thai conventional text font) over the modern font type (Roman-like Thai font) when presented with web pages. However, font size preferences varied depending on the age group. Younger adults preferred font sizes of 14 and 16 points over 12 points, while older adults preferred 16 points over 12 and 14 points. Based on the study's findings, it is recommended to use the conservative font type for both younger and older adults.

The appropriate font size depends on the font type used. For the conservative type, font sizes 12 points or larger are recommended for younger adults, while 14 points or larger are recommended for older adults. For the modern font type, 14 points or larger font sizes are suitable for younger adults, while 16 points or larger are acceptable for older adults. The study by Kamollimsakul, Petrie & Power (2014a) involved a viewing distance of approximately 57 cm between the eyes of 42 participants and the monitor. However, the calculation of visual angles should be based on the Bo Baimai height.

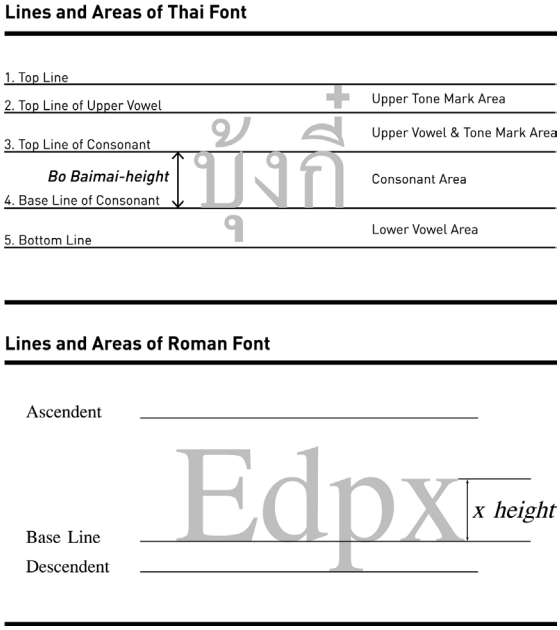
It is important to note that determining the visual angles for each point size of the conservative and modern fonts tested in the experiment is not feasible, as the names of the fonts were not provided in the study, and their Bo Baimai height is unknown. Moreover, the formula proposed by Legge & Bigelow (2011) for calculating visual angles from point unit to degree is not applicable in this case, as the given formula was formulated under the condition of the viewing distance of 40 cm, whereas the viewing distance in the study by Kamollimsakul, Petrie & Power (2014a) was 57 cm.

Although Legge & Bigelow (2011) have proposed a formula to calculate visual angles from point unit to degree, based on Bo Baimai height criteria, this formula may not be suitable for Thai fonts due to the structural dissimilarities between Thai and Roman fonts. The Thai writing system consists of horizontally composed consonants, vowels, signs, and marks, whereas some vowels, tone marks, and signs are placed in the vertical space. This contrasts with other languages, such as English, which arranges all characters horizontally.

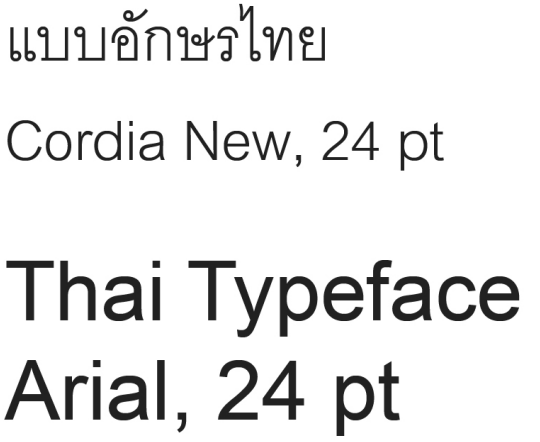
Furthermore, Figure 6 shows a comparison of the lines and areas of a Thai font (Upper) and a Roman font (Lower) (Rojarayanont, 2001). It is evident that the two font types differ in structure. Figure 7 further highlights that the consonants of Thai letterforms are smaller in lowercase compared to Roman fonts, which is influenced by the number of vertical lines and arranging areas being more than in Thai fonts. Therefore, it is essential to consider these structural differences in Thai fonts before applying the formula proposed by Legge & Bigelow (2011) to calculate visual angles.

Regarding text in books and newspapers in Thailand, keeping the text font size within 12 to 16 points is essential. However, it should be at most 7 points for packaging, as Punsongserm, Sunaga & Ihara (2017a) recommended. This is crucial for readability and accessibility for all readers. We measured the Bo Baimai height of Cordia New and TH Sarabun New typefaces at point sizes 12, 14, and 16. For Cordia New, the Bo Baimai heights at these point sizes were 1.693 mm, 1.97 mm, and 2.252 mm, respectively. For TH Sarabun New, the Bo Baimai heights at these point sizes were 1.66 mm, 1.931 mm, and 2.208 mm, respectively. At 7 points, the Bo Baimai heights for Cordia New and TH Sarabun New were 0.983 mm and 0.963 mm, respectively. We observed that the Bo Baimai heights of Cordia New and TH Sarabun New at point size 16 are 2.252 mm and 2.208 mm, respectively. This is similar to the x-height of Times New Roman at 14-point size, which is 2.209 mm. However, because the Thai and Roman letterforms differ, they cannot be directly compared. Thai conventional text fonts have certain letter features that make them more complex and require a larger size to be legible.

Conversely, using the typical point sizes 12, 14, and 16 would result in a Bo Baimai height ranging from 1.66 to 2.252 mm.



» **Figure 6:** *Upper: Lines and areas of a Thai font. Lower: Lines and areas of a Roman font (Rojarayanont, 2001)*



» **Figure 7:** *Comparing Thai and Roman fonts of the same point size with different typefaces (Cordia New and Arial)*

At a viewing distance of 40 cm, these physical sizes would convert to visual angles of 0.2378° and 0.3226°, respectively, which are well above the minimum legibility threshold of 0.2000° for most readers. However, in some cases where smaller point sizes are used, such as 10, the Bo Baimai height would be 1.411 mm (for Cordia New) or 1.383 mm (for TH Sarabun New). In these cases, the corresponding visual angles would be 0.2021° and 0.1981°, respectively, which are still acceptable to most readers.

Therefore, when defining text size with point measurement on Thai mobile applications, it is essential to consider the readability for general readers. A minimum size of 10 points for standard Thai text fonts is acceptable, whereas a size of at least 12 points is recommended for all readers. This ensures that the text is easily legible and accessible for all users, regardless of their visual abilities.

A recent study by Punsongserm (2023) examined the legibility of different text fonts, namely FT Manifest UD, Cordia New, and TH Sarabun New, with 36 Thai consonants at varying viewing distances. A sample of 31 Thai volunteers, comprising 12 males and 19 females aged between 18 and 60 and categorised into three groups- adolescent-young adults, older adults, and individuals working in graphic design and related fields- participated in the study. The study's findings revealed that perceiving Thai text letterforms at visual angles greater than 0.2000° can significantly improve their legibility compared to lower visual angles. Specifically, at a visual angle of 0.2387°, the average percentage of correct responses ranged from 92.29 to 93.19, while at a visual angle of 0.1790°, the average percentage of correct responses was between 80.92 and 86.8. However, at a visual angle of 0.1432°, the average percentage of correct responses ranged from 70.79 to 77.06, and at 0.1432°, it was between 62.90 and 72.31. These findings could be informative in selecting the appropriate font and visual angle to enhance the legibility of Thai text.

Colour Contrast

In Thailand, the Thai Web Content Accessibility Guidelines 2010: Document Number 1 Version 2.0 (Ministry of Digital Economy and Society, 2010) and the Government Website Standard Version 1.0 (EGA, 2012) have defined the contrast ratios of text and background colour based on WCAG 2.0, 2.1, and 2.2. These guidelines focus on minimum contrast (Level AA) and enhanced contrast (Level AAA) (Worldwide Web Consortium: W3C, 2016a; Worldwide Web Consortium: W3C, 2016b; Worldwide Web Consortium: W3C, 2022a; Worldwide Web Consortium: W3C, 2022b; Worldwide Web Consortium: W3C, 2023a; Worldwide Web Consortium: W3C, 2023b). The visual presentation of text and images of text must have a contrast ratio of at least 4.5:1 for minimum contrast (Level AA), except for large-scale text and its images, which must have a contrast ratio of at least 3:1.

Additionally, for enhanced contrast (Level AAA), the visual presentation of text and images of text must have a contrast ratio of at least 7:1, except for large-scale text and its images, which must have a contrast ratio of at least 4.5:1. These guidelines ensure that web content in Thailand is accessible to all, regardless of visual ability.

Furthermore, as per the Government Website Standard and Government Website Standard Version 2.0 (EGA, n.d.), Thai websites must adhere to the guidelines set by the Worldwide Web Consortium: W3C, following the Web Content Accessibility Guidelines 2.0: WCAG 2.0 on the A-Level Success Criterion (A). In addition, the Government Mobile Application Standard Version 1.0 (EGA, 2015) has recommended considering readability and visibility when choosing colours and avoiding combinations that hinder these aspects. However, it is worth noting that this standard does not delve into the specifics of contrast ratio or reference the WCAG.

We considered using the CCA version 3.2.1 application to measure the standard contrast ratios that conform to the WCAG 2.0, 2.1, and 2.2 in the selected Thai mobile applications. In this way, we can ensure that the mobile application is accessible to all individuals, including those with visual impairments. After carefully reviewing each mobile application, we focused solely on the WCAG 2.1 results that the CCA identified as having one or more errors that did not pass.

Based on the data presented in Tables 4 and 5, the CCA application has revealed that the contrast ratios for the selected mobile application for regular text did not meet (did not pass) the WCAG 2.1 enhanced contrast (Level AAA) requirement of a 7:1 ratio. Nevertheless, some contrast ratios met the WACG 2.1 requirement for large text with a 4.5:1 contrast, and 29.92% of them passed the test.

When we consider WCAG 2.1 results of minimum contrast (Level AA) in Tables 4 and 5, it is worth noting that some regular text with a 4.5:1 contrast ratio requirement passed the test with a 29.92% pass rate. In comparison, some large texts with a 3:1 contrast ratio requirement also met the criteria and had a higher pass rate of 55.12%.

Some mobile applications had trouble meeting the minimum contrast ratios WCAG 2.1 (Level AA) required. Specifically, RDU รู้เรื่องยา and สมุดสุขภาพผู้สูงอายุ (Bluebook) had many errors in meeting these standards, as shown in Table 4. In contrast, some mobile applications are quite accessible when displaying large text with a contrast ratio of at least 3:1. Examples of such applications include ทางรัฐ (Thang Rath; Table 4), สมุดสุขภาพ (Smud Sukhaphap; Table 4), and ภาษีไปไหน (Phasi Pai Nai; Table 5).

The role of colour contrast in enhancing the readability of text on digital screens is significant.

Numerous studies have investigated the impact of colour contrast on reading performance and preferences. For instance, Kamollimsakul, Petrie & Power (2014b) revealed that the choice of colours used on webpages could significantly impact the performance and preferences of both young and older adults using Thai language websites. Interestingly, the study found that commonly used colour combinations such as black on white, white on black, and sepia on off-white had no apparent effect on task completion rate or reading time for both age groups. However, there were noticeable differences in colour preferences between the two groups. Younger adults preferred black text on a white background or sepia text on an off-white background, while older adults favoured black text on white backgrounds. Based on these findings, the study recommended using black text on a white background for both age groups and sepia text on an off-white background, particularly for younger users. The study also advised all web users to avoid white text on black backgrounds. These insights provide a valuable foundation for evidence-based design guidelines for Thai websites and mobile applications that cater to younger and older users.

Similarly, Zorko et al. (2017) explored the impact of foreground and background colours on readability on digital screens. The research findings were consistent with those obtained for readability on printed materials, with black text on a white background being the most readable combination. Interestingly, the group reading this sample took the longest average time but made the fewest mistakes. The study also revealed that the black foreground-white background combination is the least stressful for the eyes. However, black text on a yellow foreground is the least readable colour combination, with the highest number of mistakes. Surprisingly, the study found that green text on an orange background and red text on a green background produced unexpected results. Even though these combinations are proven to be the least readable on printed materials, this research shows that they are suitable for reading on a digital screen.

Furthermore, Ojanpää & Näsänen (2003) examined the effects of luminance and colour contrast on the search for information on display devices. The study found that visual search times, the number of eye fixations, and mean fixation durations increased strongly with decreasing luminance contrast despite the presence of colour contrast. Thus, moderate or even high colour contrast does not guarantee quick visual perception if the luminance contrast between characters and background is small. Therefore, good visibility of alphanumeric information in user interfaces requires clear luminance (brightness) difference between foreground and background.

The colour contrast used in digital design can significantly affect user experience. These studies provide valuable insights into choosing appropriate colour combinations for digital screens. Further research is needed to explore the impact of contrast ratios and colours in web and mobile application design.

Table 4 (part 1)

Errors of colours and contrasts found in Thai government mobile applications (1)

Application Name	Colour and Contrast						
	Foreground (Hex colour code)	Background (Hex colour code)	Contrast Ratio	WCAG 2.1 Results			
				AA		AAA	
				Regular Text	Large Text	Regular Text	Large Text
ทางรัฐ (Thang Rath) Version 2.5.0	#797979	#FFFFFF	4.4:1	×	✓	×	×
	#2F6447	#FBFFFB	6.9:1	✓	✓	×	✓
	#FFFFFF	#3D855C	4.461:1	×	✓	×	×
	#FEFEFE	#78C07C	2.2:1	×	×	×	×
	#3E865C	#FFFFFF	4.4:1	×	✓	×	×
RDU รู้เรื่องยา Version 1.5.9	#FCFFFF	#F5C144	1.7:1	×	×	×	×
	#FFFFFF	#52A8DD	2.6:1	×	×	×	×
	#FFFFFB	#A0B965	2.2:1	×	×	×	×
	#666666	#FFFFFF	5.7:1	✓	✓	×	✓
	#FFFFFF	#E78E48	2.5:1	×	×	×	×
	#9D9D9D	#FFFFFF	2.7:1	×	×	×	×
	#E68E49	#FFFFFE	2.5:1	×	×	×	×
	#CBCBCB	#FFFFFF	1.6:1	×	×	×	×
	#FFFFFF	#EAA05D	2.2:1	×	×	×	×
	#F9E2CC	#EAA05D	1.7:1	×	×	×	×
	#666666	#FFFFFF	5.7:1	✓	✓	×	✓
	#FFFFFF	#A267A4	4.2:1	×	✓	×	×

Table 4 (part 2)

Errors of colours and contrasts found in Thai government mobile applications (1)

Application Name	Colour and Contrast						
	Foreground (Hex colour code)	Background (Hex colour code)	Contrast Ratio	WCAG 2.1 Results			
				AA		AAA	
				Regular Text	Large Text	Regular Text	Large Text
RDU รู้เรื่องยา Version 1.5.9	#FCFDFB	#B080AF	3.1:1	×	✓	×	×
	#A267A4	#FFFFFF	4.2:1	×	✓	×	×
	#B0B0B0	#FFFFFF	2.2:1	×	×	×	×
	#FFFFFF	#F4BF57	1.7:1	×	×	×	×
	#F4BF58	#FFFFFF	1.7:1	×	×	×	×
	#F9FFF7	#9BC556	2:1	×	×	×	×
Clicknic Version 3.4.14	#5F605F	#EBEEF0	5.4:1	✓	✓	×	✓
	#9D9D9D	#DFDFDF	2:1	×	×	×	×
	#68C0D4	#F6F5F5	1.9:1	×	×	×	×
	#427F8E	#F5F5F7	4.1:1	×	✓	×	×
	#6A6A6A	#F5F5F5	5:1	✓	✓	×	✓
	#5E5E5E	#EAEAEA	5.4:1	✓	✓	×	✓
	#ADADAD	#EAEAEA	1.9:1	×	×	×	×
	#FFFFFF	#81CBDD	1.8:1	×	×	×	×
	#747474	#FFFFFF	4.7:1	✓	✓	×	✓
	#9D9D9D	#FFFFFF	2.7:1	×	×	×	×
	#666666	#FFFFFF	5.7:1	✓	✓	×	✓
	#68C0D4	#FFFFFF	2.1:1	×	×	×	×
สมุดสุขภาพผู้สูงอายุ (Bluebook) Version 2.8.2	#FFFFFF	#4BA2D7	2.8:1	×	×	×	×
	#4CA3D6	#FFFFFF	2.8:1	×	×	×	×
	#E8AC43	#FFFFFF	2:1	×	×	×	×
	#4A78ED	#FFFFFF	4:1	×	✓	×	×
	#D83289	#FFFFFF	4.4:1	×	✓	×	×
	#7F7F7F	#FFFFFF	4:1	×	✓	×	×
	#4CA5D7	#EAEAEA	2.3:1	×	×	×	×
	#57A45A	#EAEAEA	2.5:1	×	×	×	×
	#E7AC43	#EAEAEA	1.7:1	×	×	×	×
	#C92F23	#EAEAEA	4.459:1	×	✓	×	×
	#55AC57	#FFFFFF	2.8:1	×	×	×	×
	#C82F22	#FFFFFF	5.4:1	✓	✓	×	✓
	#FFFFFF	#64C13D	2.3:1	×	×	×	×
	#4697DE	#EFFCFE	3:1	×	×	×	×
	#5B5B5B	#FFFFFF	6.8:1	✓	✓	×	✓
สมุดสุขภาพ (Smud Sukhaphap) Version 2.0.0	#E05244	#FAFAFA	3.7:1	×	✓	×	×
	#FFFFFF	#468E60	4:1	×	✓	×	×
	#AE4745	#FFFFFF	5.5:1	✓	✓	×	✓
	#747474	#FFFFFF	4.7:1	✓	✓	×	✓
	#4E4E4E	#EBEBEB	7:1	✓	✓	×	✓
	#9D9D9D	#FAFAFA	2.6:1	×	×	×	×
	#9D9D9D	#FFFFFF	2.7:1	×	×	×	×
	#FFFFFF	#428459	4.491:1	×	✓	×	×
	#6D737C	#FFFFFF	4.8:1	✓	✓	×	✓
	#30663F	#FFFFFF	6.8:1	✓	✓	×	✓
	#231E1D	#CD8270	5.5:1	✓	✓	×	✓
	#231E1D	#BE533D	3.5:1	×	✓	×	×

Table 5 (part 1)

Errors of colours and contrasts found in Thai government mobile applications (2)

Application Name	Colour and Contrast						
	Foreground (Hex colour code)	Background (Hex colour code)	Contrast Ratio	WCAG 2.1 Results			
				AA		AAA	
				Regular Text	Large Text	Regular Text	Large Text
RD Smart Tax Version 3.3.0	#5DA943	#FFFFFF	2.9:1	×	×	×	×
	#747474	#FFFFFF	4.7:1	✓	✓	×	✓
	#FFFFFF	#5DA943	2.9:1	×	×	×	×
	#6E6E6E	#F3F3F3	4.6:1	✓	✓	×	✓
	#5A5A5A	#FFFFFF	6.9:1	✓	✓	×	✓
	#F09A3A	#FDFDFD	2.2:1	×	×	×	×
ภาษีไปไหน (Phasi Pai Nai) Version 2.3.2	#696969	#FFFFFF	5.5:1	✓	✓	×	✓
	#4D91BC	#FFFFFF	3.4:1	×	✓	×	×
	#4D92BD	#FAFAFA	3.3:1	×	✓	×	×
	#FFFFFF	#4C93BE	3.4:1	×	✓	×	×
	#FFFFFF	#435993	6.8:1	✓	✓	×	✓
	#E0783C	#F7F7F7	2.8:1	×	×	×	×
	#FFFFFF	#E1783D	3:1	×	✓	×	×
	#E83628	#F7F7F7	3.9:1	×	✓	×	×
	#586270	#F7F7F7	5.8:1	✓	✓	×	✓
	#666666	#FFFFFF	5.7:1	✓	✓	×	✓
	#F2B144	#295285	4.2:1	×	✓	×	×
	#F9DD4C	#58636F	4.5:1	✓	✓	×	✓
	#54A6C9	#F7F7F7	2.6:1	×	×	×	×
PDMO Version 2.7.6	#FFFEFF	#5164C8	5.2:1	✓	✓	×	✓
	#BFBFBF	#FFFFFF	1.8:1	×	×	×	×
	#FFFEFF	#5780CE	3.9:1	×	✓	×	×
	#FFFEFF	#C89F4A	2.5:1	×	×	×	×
	#A3A3A3	#FAFAFA	2.4:1	×	×	×	×
	#FFFFFF	#4D62C5	5.4:1	✓	✓	×	✓
	#FFFFFF	#5D744B	5.2:1	✓	✓	×	✓
	#FFFFFF	#71806B	4.2:1	×	✓	×	×
	#4E2513	#CEA346	5.6:1	✓	✓	×	✓
	#FFFFFB	#9C702E	4.4:1	×	✓	×	×
	#CBCBCB	#FFFFFF	1.6:1	×	×	×	×
	#69C49C	#FFFFFF	2.1:1	×	×	×	×
	#EA6F7A	#FFFFFF	3:1	×	×	×	×
PEA Smart Plus Version 3.2.11	#6F6E75	#F3F0FD	4.49:1	×	✓	×	×
	#B89C57	#7E3AA4	2.6:1	×	×	×	×
	#FFFEFF	#7E3AA4	6.9:1	✓	✓	×	✓
	#C0B6C7	#7E3AA4	3.6:1	×	✓	×	×
	#C9C9C9	#FFFFFF	1.7:1	×	×	×	×
	#6F6F70	#F3F0FE	4.471:1	×	✓	×	×
	#EA766F	#FFFFFF	2.9:1	×	×	×	×
	#763D86	#F4F0FE	6.7:1	✓	✓	×	✓
	#A5A3AA	#F4F0FE	2.2:1	×	×	×	×
	#B99C57	#F4F0FE	2.4:1	×	×	×	×
	#FFFFFF	#E05243	3.8:1	×	✓	×	×
	#5F5F5F	#EDEDED	5.5:1	✓	✓	×	✓

Table 5 (part 2)

Errors of colours and contrasts found in Thai government mobile applications (2)

Application Name	Colour and Contrast						
	Foreground (Hex colour code)	Background (Hex colour code)	Contrast Ratio	WCAG 2.1 Results			
				AA		AAA	
				Regular Text	Large Text	Regular Text	Large Text
PEA Smart Plus Version 3.2.11	#EA766F	#F3F0FE	2.6:1	×	×	×	×
	#FFFFFF	#D5D2DF	1.5:1	×	×	×	×
	#6F6F6F	#501D5E	2.5:1	×	×	×	×
PWA Plus Life Version 3.5.2	#3465B7	#FBFBFB	5.5:1	✓	✓	×	✓
	#F8FBFF	#5153C0	6:1	✓	✓	×	✓
	#9D9D9D	#F5F5F5	2.5:1	×	×	×	×
	#FFFFFE	#EDAA47	2:1	×	×	×	×
	#FFFFFE	#3363B8	5.8:1	✓	✓	×	✓
	#F5F9FC	#4C81AC	3.9:1	×	✓	×	×
	#4878B1	#FEFFFF	4.6:1	✓	✓	×	✓
	#F5F9FB	#55A4C9	2.6:1	×	×	×	×
	#6D737C	#FFFFFF	4.8:1	✓	✓	×	✓
	#3878F6	#FFFFFF	4:1	×	✓	×	×
	#FFFFFF	#3878F6	4:1	×	✓	×	×
	#FDFFFF	#74BCDA	2.1:1	×	×	×	×
	#FFFFFF	#72B467	2.5:1	×	×	×	×
	#FEFFFF	#4878B0	4.6:1	✓	✓	×	✓
	#446F8D	#DCEDF5	4.476:1	×	✓	×	×
	#565656	#EDEDED	6.3:1	✓	✓	×	✓
	#FFFFFF	#6DA5F8	2.5:1	×	×	×	×
	#FFFEFE	#75D9BF	1.7:1	×	×	×	×

Conclusions

The proliferation of mobile applications has become an integral part of our daily lives, providing us with unparalleled convenience and efficiency for various purposes. The impact of mobile applications has also revolutionised how we interact with government services, offering citizens fast and efficient access to government-related information and services.

In line with this, Thai government mobile applications play a crucial role in the digital transformation of government services. A current technical review was conducted to evaluate the legibility of Thai typefaces, type sizes, and colour contrast in mobile applications provided by Thai government offices. One of the key findings of our study is that Thai web and mobile standards require more suitable fonts and sizes. We identified two main categories of Thai typefaces: conventional and Roman-like Thai fonts. We found that most Thai mobile applications use letter sizes of at least 1.2 mm in Bo Baimai height, but some use smaller sizes that may prove challenging to read. Choosing an easy-to-read font size is essential to improving user accessibility. The smallest type sizes for body text ranged from 1 to 1.7 mm.

We also found that contrast ratios for regular text in selected mobile applications did not meet the WCAG 2.1 enhanced contrast requirement of a 7:1 ratio. However, some contrast ratios for large text meet the 4.5:1 requirement. Some regular text with a 4.5:1 contrast ratio requirement passed the WCAG 2.1 minimum contrast test, whereas some large text with a 3:1 contrast ratio requirement also met the criteria. The study identified typographical issues that may arise in these mobile applications. It gained a deeper understanding of the subject matter.

However, the study has research gaps and limitations that future research must address.

The study focused solely on Android mobile applications, and future research should also investigate iOS applications. Since both Android and iOS mobile applications have a broad user base in Thailand, investigating both platforms would provide a better understanding of the typographical concerns in Thai government mobile applications. The study only focused on typographical concerns and did not cover the usability of mobile applications. Future research should investigate the usability of Thai government mobile applications to identify any issues that may affect user experiences.

Moreover, the study did not consider the impact of different lighting conditions on the legibility and visibility of Thai typefaces, type sizes, and colour contrast in mobile applications. Investigating the effect of different lighting conditions would provide insight into how typographical concerns affect user experiences in different environments.

The study only measured physical type sizes based on the Bo Baimai height measurement without considering other factors that could affect legibility, such as letter spacing, line spacing, and font style.

Future research should consider these factors to provide a more comprehensive understanding of the typographical concerns in Thai government mobile applications.

The study only used a colour contrast analyser application to measure colour contrast without considering the visual perception of users with different types of colour vision deficiencies. Investigating the impact of different kinds of colour vision deficiencies on the legibility of Thai typefaces and colour contrast would provide insight into how to design mobile applications accessible to all users.

Lastly, the study did not involve user testing to evaluate the legibility and visibility of Thai typefaces, type sizes, and colour contrast in mobile applications. Conducting user testing would provide a better understanding of the impact of typographical concerns on user experiences and identify any issues that may affect user satisfaction.

To conclude, future research should investigate the impact of different letter spacing, line spacing, and font styles on the legibility of Thai typefaces in mobile applications. Developing guidelines and standards for Thai typefaces, type sizes, and colour contrast in mobile applications that consider the needs of users with different types of colour vision deficiencies is also necessary.

Conducting user testing to evaluate the legibility and visibility of Thai typefaces, type sizes, and colour contrast in mobile applications is crucial. This may necessitate specialised blur simulation equipment such as blur glass filters and cataract simulation goggles. Collaboration with participants who have normal visual acuity, as well as those who are visually impaired and elderly, is equally important.

These efforts would provide insight into how to design mobile applications that are more user-friendly, accessible, and satisfying for all users.

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