# Traditional Mongolian on Modern Devices

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## ABSTRACT

Computer operating systems have been slow to adopt the Traditional Mongolian script for the Mongolian language due to its vertical, left-to-right orientation. Prior research shows that Webkit-based browsers struggle to display the Traditional Mongolian script, while Blink-based browsers like Google Chrome are able to display Mongolian text to a certain extent. However, this research is outdated and fails to look at these issues with reference to the operating system being used to host each browser. This study will determine the accessibility of the Mongolian script on modern computer systems by examining the problems that major operating systems have with the Traditional script. Data was collected through a needs assessment, where quantitative analysis of the data was employed. Operating systems included Android 12, iOS 15, and Windows 10, in which Google Chrome, Safari, Microsoft Edge, and Samsung Internet were hosted. Initial results showed that browsers ran in iOS contained a higher amount of text rendering problems compared to other variables, while browsers ran in Android and Windows had the most amount of support and were the most usable. Text rendering problems generally varied based on the operating system being used rather than the browser displaying the text, meaning that Mongolian support problems were moreso dependent on the operating systems. These findings indicate that Mongolian display problems lie more with the operating systems themselves, meaning that distributors like Apple, Android, and Windows should consider which aspects of localization support should be focused on when providing language options for the Traditional Mongolian script.

## Background

The Traditional Mongolian Script was the first and most commonly used script for writing the Mongolian language. Though it was replaced by the Cyrillic script in 1946, it is still used for official documents in Mongolia, and the Mongolian government has announced plans to replace the Cyrillic script with the Traditional script by 2025. The Traditional script is written vertically and read from left-to-right, with letters in each word connecting like in Arabic or English cursive (Figure 1). Due to the widespread use of the Cyrillic alphabet and the top-to-bottom alignment of the script, the Traditional script has a limited history of being used on computer systems. Many early operating systems stuck to the Cyrillic script, while digital Mongolian libraries (Garmaabaazar & Maeda, 2007) made attempts at digitizing the alphabet (Bator, 2005). While the Traditional script has been included in Unicode and ISO/IEC 10646 standards since 1999 (Erdenechimeg et al., 1999), most operating systems did not support the Traditional script until 2007, with the release of Windows Vista. This means that Mongolian-speakers relied on third-party software until recently, and, due to the vertical orientation of the script, a majority of software vendors and operating systems would use the Cyrillic script as the default for displaying and typing Mongolian. The vertical orientation of the script also poses a variety of problems for mobile displays, the scope of which is unknown as most mobile systems only displayed local regional languages or only supported English until recent years. This study will evaluate the extent to which the Mongolian Traditional script is supported across the most popular operating systems– Windows, Apple, and Android (NetApplications, 2020) -- and what support features are missing in comparison to the "default" English features available.

**Figure 1.** Mongolian writing direction.

## Literature Review

### Overview

The Unicode Standard is the near-universal standard for encoding and handling of text and glyphs used in written language for computer software (Addison-Wesley, 2003). While some computer systems may not support or display all Unicode characters (such as certain emojis or letters), major operating systems such as Microsoft Windows and macOS use the Unicode model for text encoding. It is the most widely-used model for Mongolian encoding and has a history of formatting problems such as the lack of formal "rules" for identifying if a character is contained within a word or isolated on its own, causing the script to behave unexpectedly and disjointedly when used in Unicode-based systems (Liang, 2017). Certain browsers are also unable to display connected Mongolian letters or hyphenate Mongolian text (Ishida, 2022). While a document regarding the layout standards for displaying Mongolian text in a variety of coding languages has been drafted (Nasun-urt & Chitu, 2020), most browsers fail to follow these standards (Ishida, 2022) and the degree to which that is true for current browsers and operating systems is unknown. Due to this gap in understanding, my research will examine the areas of language support that are inadequate or otherwise problematic for Mongolian on operating systems and web browser display and use, as well as describe how these problems appear for the user.

### Vertical Formatting

Previous research has focused on the poor formatting of Mongolian text within web browsers and eReaders and has found that vertical Mongolian text lacks support across all browsers. Analysis done by the World Wide Web Consortium shows that the CSS *writing-mode:vertical-lr* property is not supported by all browsers, though necessary for displaying the Mongolian Traditional script correctly. This research also describes an issue that

certain WebKit-based browsers have, in which vertical text orientation is supported but displayed incorrectly with the Mongolian script (Ishida, 2022).

Earlier research done on the *writing-mode:vertical-lr* CSS property and its support across multiple web browsers shows that Firefox, Chrome, Safari, and Edge browsers were able to display vertical text that ran from left to right, while Android browsers did not support vertical text at all. When trying to display vertical Mongolian text, however, Firefox, Chrome, and Edge browsers were able to display the text correctly while Safari and Android browsers could not. All mentioned web browsers could not display textarea boxes or selection boxes with vertical text in them correctly, with the exception of Android being able to display vertical textarea selection boxes (World Wide Web Consortium, 2016).

## The Mongolian Encoding Model

Research done on the Unicode encoding model for Mongolian, used by virtually all operating system vendors, indicated a variety of problems that the model had, unique to Mongolian. As the Traditional Mongolian script has specific features and rules dependent on letter position and form, the Unicode encoding model expressed difficulties with recognizing letters in isolation and within a word, and lacked a proper algorithm for determining contextual rules and design. (Khaltarkhuu & Maeda, 2008). This results in certain Mongolian words displaying a disjointed tail, unintended positional forms, and overall unexpected behavior (Liang, 2017).

## Useability

With Unicode Standard 3.1, Microsoft revealed support for the Mongolian script using OpenType Mongolian fonts (Microsoft, 2002). Researchers conducting a survey on the useability of the Traditional Mongolian script Unicode model described problems that actual users had while using the script. These users expressed difficulty using multiple Mongolian fonts, as sizing and formatting is not standardized for the Traditional Mongolian script. Many fonts were too small in comparison to others, and most stated that even larger font sizes that might be adequate for viewing Latin text were not adequate for Mongolian Traditional text. This study also found that users had problems with line breaks and word wrapping for the vertical Traditional script, resulting in errors with rendering the Traditional script. Overall, the model designed for typing the Traditional script was confusing for most users surveyed (Batjargal et al., 2011).

This study also found several earlier errors in the Unicode encoding model for the Traditional Mongolian script. Most fonts had difficulties rendering words with vowel harmony properties correctly, and displayed the wrong end forms of letters. Overall, Mongolian fonts had problems forming suffixes, in which the beginnings, endings, and middle forms of letters were rendered incorrectly and without a standardized form (Batjargal et al., 2011).

## Mongolian Requirements

The World Wide Web Consortium's Internationalization Task Force describes necessary components for formatting the Mongolian Traditional script "correctly" on web browsers. Text written in the Mongolian Traditional script should be formatted vertically going from left-to-right, with a page scrolling horizontally rather than the vertical scrolling that English webpages use. Punctuation marks cannot be used at the beginning of a line, and all punctuation must be flipped so that it matches the vertical script, rather than the horizontal Latin script. Latin letters should be flipped as well. When highlighting text, the cursor should be flipped and oriented horizontally to accommodate for the vertical script (Nasun-urt & Chitu, 2020).

Along with that, horizontal layout features and elements should be flipped and oriented vertically, and vice-versa. Text fields and buttons should be displayed vertically, as should select boxes and labels. The overall

page layout and progression should be so that the page direction is rotated and scrolls vertically. Scroll bars should scroll horizontally instead of vertically in textarea boxes as well. However, images should remain the same orientation and should not be rotated. The image should not break the words or text surrounding it, and earlier rules for mixed-media apply as well (Nasun-urt & Chitu, 2020).

## Methods

### Rationale

This study examines the extent to which the Traditional Mongolian script is supported and available to users on both computer systems and mobile devices alike. The goal is to paint a clearer picture of which areas most systems have no problem providing Mongolian support for, and which areas are widely lacking. This is necessary for software developers and programmers to understand what must be done to resolve the issue, and where the users run into problems that localization teams may fail to recognize initially.

A gap analysis study was used to see the areas where most operating systems provided Mongolian language support, and where they lacked support. A quantitative analysis method was employed, as it would allow me to view the data from an analytical, problem-solving perspective that qualitative research methods would fail to see. Reviewing the varying degrees of Mongolian language support and localization efforts of more than one operating system enabled me to see how these issues persisted across a wide array of systems and to compare the adequacy of localization efforts between these operating systems. Examining localization features within the operating system itself, rather than just looking at support problems in web browsers as in earlier research, also allowed me to view my research on a larger scale. This gives me a better idea of the overall problem that Mongolian users run into due to lack of support and localization efforts, rather than just viewing the individual problems themselves that the computers run into.

### Samples

A set of three devices was sampled for this study– one running on iOS 15, one running on Android 12, and one running on Windows 10. All devices were up-to-date, and the mobile devices were the most recent models as of the time of this study, to ensure that no "false negatives" were recorded– i.e. no issues would occur due to a problem with outdated software or bugs that had already been fixed and no longer applied. Windows, iOS, and Android were all sampled because of their popularity as the most commonly used operating systems across the world. The quality and level of localization for the Mongolian language and locale was examined for language features that these three operating systems supported or should support, such as display language or keyboard language. The text layout and display of the Traditional script was also reviewed on web browsers, where Google Chrome was looked at for all three operating systems. For each individual operating system, I looked at the "default" browsers that come with each OS– Safari on iOS, Samsung Internet on Android, and Microsoft Edge on Windows 10.

### Research Instruments

A checklist of features was used to examine the quality of Mongolian language support on both web browsers and within the operating system settings. This included features such as the display language of the operating system, vertical orientation of Mongolian text as default, etc., so that the support or lack of support of any feature by any operating system could be recorded. This checklist was based off of earlier gap analysis research done on this topic, however was altered to include a wider array of operating systems and browsers, along with

localization features such as the operating system display language or keyboard language. Whether or not a feature was supported or not supported "correctly" was based off of pre-existing standards already in-use by Unicode and the W3C. Testing rigs in-use by the W3C were used to check whether web browsers properly supported the *writing-mode:vertical-lr* CSS property and thus properly supported vertical Mongolian text (Ishida, 2016). See Appendix A for the full checklist.

Procedures

To begin, devices running Android, iOS, and Windows 10 operating systems had to be gathered for review. The most current and up-to-date models were chosen and the software was checked for any necessary updates. These devices included a Samsung S21 running Android 12, an iPhone 13 running iOS 15, and a Dell Inspiron 7537 running Windows 10 Home. All three devices had English set as the default language, and all three were bought in the United States.

All three devices were reviewed based on their inclusion of Mongolian localization features (See Appendix). Features such as autocorrect and live-captioning were reviewed only on mobile devices (Android and iOS) and not on Windows 10, as these features are not pre-loaded onto the operating system. What constituted as "supported" and "not supported" was based off of Mongolian language rules and display standards already in use. This included the lack of inclusion of a Mongolian feature (such as not being able to use or display Mongolian regardless of script), inclusion of a Mongolian feature only in Cyrillic or Latin, inclusion of a Mongolian feature only in a horizontal fashion (such as Mongolian text only being typed horizontally), or incorrect inclusion of a Mongolian feature (such as Mongolian text being only displayed partially or otherwise not according to standard). Web browser features that did not adhere to the assertion statement already included in any nonspecific testing rig were decidedly not supported (See Appendix A).

Results were recorded as either "supported", "not supported", or "partially supported," and were screenshotted for future reference. Notes regarding any unusual problems or ambiguous results were also included (See Appendix). Accessibility features and "optional" features were brought up when designing the study; accessibility features such as live-captioning, live-transcription, and text-to-speech that are necessary for Deaf/hard-of-hearing and blind users were also brought under review regardless of their support in other languages; "optional" or otherwise unnecessary features including system fonts, cursor orientation, and page layout and scrolling were recorded if they applied, but were otherwise unmentioned. Throughout the study, "computer" is used literally, and includes both mobile and desktop devices rather than only desktop devices. Non-applicable features were not included in mean, median, mode, or percentage calculations. No third-party applications other than Google Chrome that would impact the results of the study were installed, and none of the devices were altered in any way.

# Results

Across Android, Apple, and Windows systems, the language support features were split into two categories–features relating to the localization of the operating system itself, and features relating to the web browsers' ability to support and display Mongolian text, including certain CSS and HTML properties. "Optional" features such as changing the system font that are available for the English language but are not necessary for using the language or computer/phone were not included.

Localization

Of the three operating systems being examined, no operating systems had adequate localization options for the Mongolian Traditional script. Both Android and iOS did not have any option to set the system display language as Mongolian using the Traditional script, with iOS completely lacking a Mongolian language setting. Windows 10 did have the option to set the system language as Mongolian (Traditional), however this resulted in the system displaying certain text in the horizontal Traditional script, Cyrillic script, and in English or the Latin script

All systems lacked a vertical Traditional Mongolian keyboard. iOS 15 lacked a Mongolian keyboard completely. Both Android 12 and Windows 10 had Cyrillic and Traditional Mongolian keyboards, however the Traditional script keyboards could only be typed horizontally and did not have any cultural-specific punctuation marks used on paper. These keyboards did not have autocorrect, word suggestion, or speech-to-text options for the Mongolian keyboard.

No accessibility features were available in any language other than English for all three operating systems, except on Android 12, where text-to-speech was available to use. However, other features, such as live-captioning and live-transcription, that would be necessary for Deaf and hard-of-hearing users were not available for Mongolian.

**Figure 2.** Localization features for different operating systems as indicated by whether or not they had (pass), did not have (fail), or partially had (could not be determined) available localization features.

## Browser Support

Each operating system was also examined based off of its ability to display vertical Mongolian text within a web browser. Multiple web browsers were reviewed; including Google Chrome in Android 12, iOS 15, and Windows 10; Samsung Internet in Android 12; Safari in iOS 15; and Microsoft Edge in Windows 10. All web browsers fully supported the *writing-mode:vertical-lr* CSS property, meaning that all browsers could display vertically-oriented text that started on the left side of the the screen, and wrapped from left to right, as Mongolian text is oriented. This also includes proper display of table cells and table columns with vertical text in them.

All browsers used on Android 12 and Windows 10 (Google Chrome, Samsung Internet, and Microsoft Edge) were able to correctly display vertically-oriented Mongolian text by default using the *writing-mode:vertical-lr* CSS property. This includes correct joining of the letters, text that begins on the left side of the screen, and proper formatting of images between/within vertical Mongolian text. Google Chrome and Samsung Internet had difficulties highlighting and copying vertical Mongolian text, however Chrome and Microsoft Edge did not, and oriented the select cursor to match the use of vertical Mongolian text.

iOS browsers (Google Chrome and Safari) were not able to correctly display vertically-oriented Mongolian text, as the letters were not joined nor formatted correctly (See Appendix B). Both browsers could correctly display an image within the vertical text, but ultimately could not format the Mongolian text as per standard. No browsers on any operating system could display vertical Mongolian text within single and multi-lined textarea boxes, nor could they display the text within a select box. Selected items and options would default to horizontal text, and textarea input boxes and text displayed horizontally as well (See Appendix C).
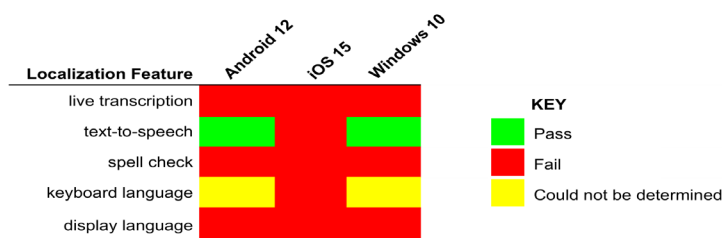


| Localization Feature | Android 12 | iOS 15 | Windows 10 |
|---|---|---|---|
| live transcription | Fail | Fail | Fail |
| text-to-speech | Pass | Fail | Pass |
| spell check | Fail | Fail | Fail |
| keyboard language | Could not be determined | Fail | Could not be determined |
| display language | Fail | Fail | Fail |

KEY
- Pass (green)
- Fail (red)
- Could not be determined (yellow)

| Android | | iOS | | Windows | | |
| Chrome | Samsung Internet | Chrome | Safari | Chrome | Edge | *writing-mode:vertical-lr* property |



**Figure 3.** Features supported by browsers as indicated by their ability (pass) or inability (fail) to display Traditional Mongolian using the writing-mode:vertical-lr CSS property.

## Analysis

Analysis of data was purely quantitative. Results across all operating systems and web browsers were compared with each other and with overall results. Ambiguous or impartial results were included in percentage calculations, and were not counted as "supported features." This study was designed to examine the functionality of the Mongolian script on computer systems for Mongolian users and the extent to which Mongolian was supported across operating systems.

### Findings

As seen in Figure 3, no operating systems provided localization features for the Mongolian Traditional script. Two-thirds (67%) had "debatable" support for Mongolian as the keyboard language, though nothing that fit accepted standards. Of all accessibility features reviewed across all operating systems, only 1 of the 6 features (17%) supported Mongolian text at all.

All browsers supported vertical text orientation and alignment using the *writing-mode:vertical-lr* CSS property, including orientation of vertical text within a table cell or column. However, of the six browsers, only four (67%) could properly display Mongolian vertical text by default. No browsers could support or display vertical textarea or selection boxes, and all defaulted to displaying the Traditional script horizontally. Of the 14

features reviewed across six web browsers, 50% of all browser features were correctly displayed and properly supported. Of all total features reviewed across three operating systems and six web browsers, 43% of all total features were properly supported.

iOS provided the least amount of support for web browsers and in total, only being able to support 12.1% of features, compared to a mode support of 47.4% (9 of 19 features). Of these features, none were Mongolian-specific, and Mongolian was not included in localization options regardless of script like other operating systems did. Across operating systems, web browser features were consistent regardless of the browser itself, i.e., Chrome (iOS) and Safari (iOS) supported the exact same features, though Chrome on Android and Windows supported features that Chrome on iOS did not. Google Chrome, Microsoft Edge, and Samsung Internet are all Blink-based browsers, while Safari runs on WebKit. However, whether or not a browser supported or properly displayed Mongolian text features was not dependent on the browser itself and varied even using the same browser on different operating systems.

Previous research on the topic has indicated that Android browsers would fail to correctly display Mongolian text by default (World Wide Web Consortium, 2016). However, both Google Chrome and Samsung Internet running on Android 12 were able to display vertical Mongolian text correctly, and passed checks indicating that the *writing-mode:vertical-lr* property worked properly. It was also indicated that Android browsers were able to display a vertical textarea field with vertical placeholder text inside, though currently the Google Chrome and Samsung Internet browsers were unable to pass the textarea placeholder checks seen in Figure 2.

| | Android | iOS | Windows | Mean % | Range |
|---|---|---|---|---|---|
| OS Localization | 20.0% | 0.0% | 20.0% | 13.3% | 20.0% |
| Browser Support | 57.1% | 14.3% | 57.1% | 42.3% | 32.8% |
| Total | 51.5% | 12.1% | 51.5% | 38.4% | 39.4% |

**Figure 4.** Support features by operating system.

## Closing Gaps in the Research

Though earlier research and information on this topic typically split results based on the type of browsers and ignored localization features, this study addresses those gaps by looking at multiple types of browsers across multiple operating systems, alongside localization features supported by different operating systems. The design of earlier studies had also been purely barebones, providing little information about the nature of issues that users would run into when attempting to display Mongolian text or use a device with Mongolian as the set language. This study also used data from the most updated operating systems, while the most recently done study on the topic relied on data from 2016, and most information regarding the state of the Mongolian encoding model for Unicode is from much earlier. Unnecessary information regarding problems that had already been fixed was not included in this study, and information regarding new issues that had come up in new computer systems was included.

## Limitations

While reviewing areas of support related to the actual language of the operating system, there was some concern about regional lockout policies employed by some phone providers that would cause Mongolian to be unavailable or unsupported on phones purchased in America or with an American region code. There was also concern about whether or not choosing to exclude Linux and macOS systems would potentially skew the data values.

However, because newer system phone models were used, regional lockout of language support is a nonissue and only a concern with older models or tracfone systems. It was decided that the exclusion of Linux and macOS systems from the research design was of little concern, as Linux would have a wide array of language support options and would contain many nonstandard variables due to being open source; macOS systems would provide results too similar to iOS systems, as the two are both produced by Apple.

There was also debate about which features should be reviewed or not reviewed. Though the checklist of requirements used was based off of previous research, these requirements included certain "optional" features such as supporting Mongolian fonts or cursor orientation. Most studies had also only focused on desktop browsers and lacked research on localization features or mobile browsers, and accessibility features were never mentioned. It was decided that "optional" features would only include features that were not needed for fundamental features and use of the Mongolian language on any of the three devices using any of the included browsers, however "optional" features would still be kept in mind, though not included in analysis of data. Localization features would be included in research and data alongside web browser features, as they impact the useability of a device in Mongolian just as web browser features do. Accessibility features would be included for similar reasons; they impact the useability of a device for users just as localization and web browser features do.

## Implications

This research can provide computer programmers and localization teams with information regarding which areas of Mongolian localization and support need further improvement. The study provides the knowlesge necessary for future localization efforts, as it outlines which areas are most problematic and need to be focused on when creating Mongolian language options for users. In addition, this document also provides recent and updated information regarding support of the Traditional Mongolian script with reference to the operating system being used. As browsers release new updates and as the Mongolian encoding model is developed, older research documents outlining issues that the Traditional Mongolian script faces become outdated. Earlier research done on this topic acknowledges the need for updated guidelines as the situation regarding Mongolian support develops (Batjargal et al., 2011). Therefore, this study can provide an updated and recent description of issues and gaps in Mongolian language support online, and can inform both computer programmers and web users of the areas of Traditional Mongolian localization that should be focused on and improved (Ishida, 2016).

## Areas for Future Research

The scope of this study can spur future research on this topic and similar topics in the field. Future studies could be conducted on the current state of localization support with regards to other non-Western languages or scripts that are currently unavailable on computers and mobile devices. This study's subjects could also be broadened to include open-source projects and operating systems like Linux, where language support options are not limited to what the operating system or browser manufacturers provide. As the World Wide Web Consortium's requirements for Traditional Mongolian text display requires webpage layouts to rotate or provide page elements that match the script's vertical orientation (Nasun-urt & Chitu, 2020), computer programmers and graphic designers may wish to research how they can design user interfaces for their respective applications that fit vertical Traditional Mongolian text.

## Acknowledgments

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%3A%7B%22share%22%3A-
1%7D%2C%22id%22%3A%22platformsMobile%22%2C%22dateInterval%22%3A%22Monthly%22%2C%
22dateStart%22%3A%222019-11%22%2C%22dateEnd%22%3A%222020-
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